FRONTISPIECE.

See page 28.

HISTORY & PROGRESS

OF

The Steam Engine.

BY ELIJAH GALLOWAY.

WITH AN

EXTENSIVE APPENDIX.

BY LUKE HEBERT.

HISTORY AND PROGRESS

OF THE

STEAM ENGINE,

With a Practical Investigation

OF ITS

STRUCTURE AND APPLICATION:

BY ELIJAH GALLOWAY,

CIVIL ENGINEER.

TO WHICH IS ADDED,

AN EXTENSIVE APPENDIX,

CONTAINING MINUTE DESCRIPTIONS OF ALL THE VARIOUS IMPROVED BOILERS; THE CONSTITUENT PARTS OF STEAM ENGINES; THE MACHINERY USED IN STEAM NAVIGATION; THE NEW PLANS FOR STEAM CARRIAGES; AND A VARIETY OF

ENGINES FOR THE APPLICATION OF OTHER

Motive Powers,

WITH AN EXPERIMENTAL DISSERTATION ON THE NATURE AND PROPERTIES OF STEAM AND OTHER ELASTIC VAPOURS, THE STRENGTH AND WEIGHT OF MATERIALS, &c. &c.

BY LUKE HEBERT,

Editor of the Register of Arts, and Journal of Patent Inventions.

ILLUSTRATED BY

Upwards of Two Hundred Engravings.

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PREFACE.

The invention of the Steam Engine has been productive of so great a change in the arts and conveniences of life, that it may with justice be regarded as an era in the history of the world. It is true that other inventions have raised the intellectual greatness of man, far beyond the anticipations of rational conjecture; that they have enabled him to number the stars, to describe their motions, and bring within the grasp of his faculties those myriads of orbs, which had been esteemed far beyond the compass of his vision,—to direct his way unerringly across the pathless ocean,—to stop the course of rivers,—to convert he shallow brook into a spacious navigable canal,—to fertilise the barren rocks,—and change the unfrequented desart into the active theatre of his genius!

But, however great were the capabilities of man *before* the invention of the Steam Engine, they have *since* been multiplied beyond calculation. The mariner avails himself of its gigantic power, and the roaring winds and the rushing tides no longer oppose his progress over the watery deep;—the miner calls for its aid—then rivers rise vertically out of the depths of the earth, which had previously arrested his operations;—that useful mineral which is our fuel, is torn from its rocky bed to supply our hearths; and those invaluable metals are drawn from their profound recesses to form the implements and machines

which are alike essential to our national prosperity and individual comfort.

Stupendous as are the powers of the Steam Engine, they are so perfectly under control, and so nicely regulated, that it is made to separate the fine film of the silk-worm, and to realise the fairy fingers of fiction, by spinning an invisible thread! To use the elegant language of JEFFREY, "it has become a thing alike wonderful for its force and flexibility; for the prodigious power which it can exert, and for the ease and precision, and ductility with which it can be varied, distributed, or applied."

Notwithstanding the intense interest which must attach to this subject in every rational mind, but very few works on the Steam Engine have appeared before the public, and these do not possess such qualifications as to render them of much utility. Those of the cheaper class have taken too contracted a view of the subject, and are unaccompanied with investigations of the practical advantages or defects of the machines under notice; while those of the expensive kind are unnecessarily elaborate in their minute details, and their investigations are too abstruse for the comprehension of readers who have not made considerable progress in mathematical science. In the one case, therefore, the ardent seeker for information will meet with little more than amusement; and in the other, he will find the knowledge inaccessible, from the manner in which it is exhibited.

In the Treatise now presented to the reader, Mr. GALLOWAY has steered a middle course, and thereby avoided those defects which have rendered the labours of his contemporaries of very limited utility. The work was originally published about two years ago, and it has since met with so extensive a sale, as to induce the Proprietor to

send forth a new and improved edition, after having undergone a careful revisal by its Author, who has taken the opportunity of introducing some interesting and important matter, which the readers of the first edition will readily perceive and appreciate. It contains all the matter of the first edition, but in a more correct form; consisting of descriptive accounts of all the various Steam Engines that have been invented since the time of Hero the elder, (who flourished 130 years before Christ,) down to the year 1827; together with a critical and minute investigation of their merits and defects. To this portion of the work, which forms the *first* section, Mr. GALLOWAY has added a *second* section on Steam Navigation, and a *third* on Locomotive Steam Carriages.

To the original work, thus improved, has been added, in the present edition, a copious APPENDIX, which has been supplied by Mr. LUKE HEBERT, whose avocation, as Editor of the Register of Arts, and Journal of Patent Inventions, peculiarly qualifies him for the task.

On the importance of the subjects introduced into the Appendix, it will be unnecessary to dilate, as the simple statement of their nature will at once carry conviction to the mind. They are divided into eight sections, *viz.*

The first section, treats of *the nature and properties of steam and other vapours*, whose elastic forces have been employed or proposed as mechanical agents for impelling machinery; this subject, of necessity, includes a dissertation on the interesting *phenomena of heat.*

The second section, contains some preliminary observations on the construction of apparatus for the generation of steam, with descriptions of all the important, among

the very numerous, *boilers* which have been recently invented, or become the subject of patent-rights; including also a dissertation on *safety valves*, with accounts of a variety of contrivances to prevent dangerous explosions.

The third section, relates to *the constituent parts of steam engines generally*, in which their offices are separately considered, and the relative proportions, construction, and arrangement, described.

The fourth section, contains interesting accounts of a variety of newly-invented *machinery for the propulsion of steam vessels.*

The fifth section, is descriptive of the various *locomotive steam carriages* that have been recently constructed, or that are at present under a course of experimental trials.

The sixth section, contains accounts of various *engines* in which the elastic force of the vapours of *ether*, *alcohol*, *essential oils*, as well as *carbonic acid gas*, *atmospheric air*, *and water* are employed to produce motive power.

The seventh section, is descriptive of a variety of *steam engines*, many of which having been invented since the date of the last engine described by Mr. Galloway, may be regarded as a continuation of his History.

The eighth section, contains a detail of numerous experiments on *the weight and strength of materials*, besides a variety of tabular matter, conveying information of the greatest practical utility in the art of construction.

HISTORY

OF

THE STEAM ENGINE.

FIRST SECTION.

The source from which the Steam Engine, in all its varied modifications, derives its power, is a property which water possesses of becoming expanded by heat. This property begins to operate at a temperature of 40° of Fahrenheit, below which it also possesses the opposite quality of expanding by the decrease of heat. When the temperature exceeds 40°, it remains fluid until heated to 212°; it then acquires the power of passing off in an aeriform state, and becoming vapour or steam, which is an extremely light and elastic body, and may be retained in a close vessel of sufficient strength, even when it is capable, unconfined, of expanding itself to several hundreds of times the area of its prison. In its confined state, it exerts a force against the sides of the vessel proportionate to its compression; which force being applied to water, or any other matter intervening between the steam and the channel of escape, exerts itself on the intervening matter, and thereby puts it in motion.

This is the most palpable and evident property of steam, and there can be no doubt that mankind have been acquainted with it from the earliest dawn of civilisation. But there is another method of deriving power from steam, which, though equally useful, is not so easily discerned as

the former. This is the faculty which it possesses of being instantly condensed by cold, and re-converted into water By this property a partial vacuum may be produced in a vessel which was, an instant before, filled with steam; and if we suppose a tube connected with that vessel, and a well not exceeding twenty-five feet below, the pressure of the atmosphere will act upon the surface of the water in the well, and thereby raise it up through the tube and fill the vessel.

When this latter property of steam was first known, it is now impossible to determine. In the earliest experiments, the expansive force alone appears to have been applied, and that merely in an ineffective toy, known by the name of the oelopile. The first individual on record who used it, appears to have been Hero, the elder, an Alexandrian, who flourished about one hundred and thirty years before the Christian era. In his work, entitled *Spiritalia*, or *Pneumatica*, among other ingenious discoveries, he describes a machine to which motion is to be given by the force of steam. It consisted of a hollow globe, having tubular arms, running in opposite directions. These tubes had an opening at different sides, near their extremity. The globe was suspended upon centres, fixed upon pillars. One of those pillars was hollow, as also was one of the centres or axes. Steam was introduced from a cauldron, or heated vase, which, issuing through the hollow column and axis into the globe, and so through the arms into the open air, produced a rotary motion, in the same manner as water produces that of Barker's mill.

In the dark ages which succeeded the overthrow of the empires of Greece and Rome, history furnishes no instance of an attempt to use the powerful agency of steam, until the year 1563, when one Mathesius suggested the possibility of constructing a machine by which it could be worked by steam. In the year 1597, a book, printed at Leipsic, describes a "*Whirling Oelopile*," which, it is suggested, is well adapted to dispense with the services of the turnspit dog.

Up to this date we cannot trace any thing important

relative to the application of steam, excepting what we have already stated. We are unable, at this period, to form any idea as to the originality of the plans which have been named. It is impossible to state whether they were descriptions of what was generally known, or they were the invention of those by whom they were claimed. Nor should our readers be surprised at the obscurity in which these matters are involved, when they reflect, that there is frequently great difficulty in deciding who are the inventors of the most meritorious productions of our own times.

Having briefly stated what is recorded respecting the earlier history of the steam engine, when it had merely the character of a philosophic toy, we come to speak of the first attempt towards its adoption as a powerful agent.

It is described in a work by Solomon de Caus, an eminent French mathematician and engineer, published in 1615, entitled, "Les Raisons des Force mouvantes avec divers Desseins de Fontains."

The following description will explain the principle of his invention.

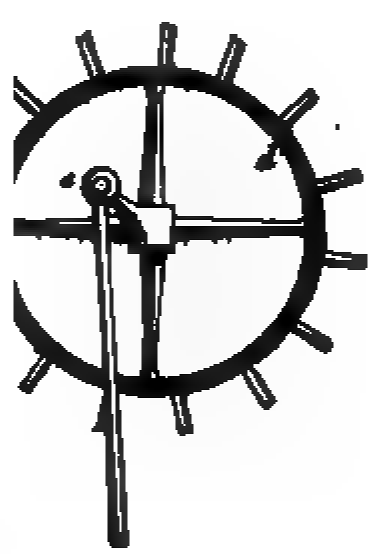
a is a spherical vessel, placed over a fire; it is furnished with two pipes, *b*, *e*. The pipe *e* is open at the top, and reaches down to the bottom of the vessel *a*. The pipe *b* is furnished with a cock *d*, and funnel *c*. The vessel being filled with water, and fire applied, steam is speedily generated upon the surface of the water, and having no other way to escape, the cock *d* being stopped, presses on the surface, and so forces it up the tube *e* into the air, causing

(*De Caus's Engine.* 1615.)

a jet, which varies in proportion to the elasticity of the steam within.

De Caus appears, also, to have been aware that a vacuum could be obtained by the condensation of steam, but we have no opportunity of knowing whether he ever thought of using it as a means of increasing the power of his machine.

The engine which next demands our attention, both on account of its importance and date, is that invented by Giovanni Branca, an Italian mathematician, who resided at Rome, at the commencement of the seventeenth century. We are indebted for our knowledge of this machine to his own account, published in 1629.* The drawing which he there furnishes must be understood rather as an ornamental illustration of his plan, than as the form in which it was actually constructed: we have, therefore, given one which we conceive to be more consistent with the end he proposed to effect by its use.



(*Branca's Engine.* 1628.)

The boiler of this engine is represented by *a*; *b* is the fire grate; *c* a small pipe, provided with a stop cock *f*; *d* is a wheel furnished with vanes; *e* is a crank which gives motion, through the medium of the suspended rod, to a

* "Le Machine diverse del Signior Giovanni Branca."

stamper for pounding drugs. The principle of action is—that steam is generated in the boiler, and rushes violently against the vanes, which causes the wheel to revolve, and thus produces a reciprocation of the rod and stamper.

This invention had remained unnoticed but by the learned, until the last few years. It is described by Partington, in his History of the Steam Engine, who goes so far as to allow Branca the merit of the *first idea*. We believe our readers will perceive that to this honour Branca has no claim. His engine is on the same principle as Hero's, only differently modified. Its ingenuity is decidedly inferior to its prototype, both in simplicity and effect.

But of all the various applications of the elastic force of steam, nothing of this period has stood so high in public estimation as a brief description of "*a fire-water work*," contained in the Marquis of Worcester's celebrated "Century of Inventions," dated 1663; the original manuscript of which is preserved in the British Museum. The following is the Marquis's own description:—

"An admirable and most forcible way to drive up water by fire, not by drawing or sucking it upwards, for that must be, as the philosopher calls it, *infra sphæram activitatis*, which is but at such a distance. But this way hath no bounder, if the vessels be strong enough; for I have taken a piece of a whole cannon, whereof the end was burst, and filled it three-quarters full, stopping and screwing up the broken end, as also the touch-hole, and making a constant fire under it; within twenty-four hours it burst, and made a great crack; so that having found a way to make my vessels, so that they are strengthened by the force within them, and the one to fill after the other, I have seen the water run like a constant fountain-stream forty feet high; one vessel of water, rarified by fire, driveth up forty of cold water; and a man that tends the work, is but to turn two cocks, that one vessel of water being consumed, another begins to force and refill with cold water, and so successively, the fire being tended, and kept constant, which the self-same person may likewise abundantly perform in the interim, between the necessity of turning the said cocks."

From this account Dr. Robinson founds an opinion that "the steam engine was, beyond all doubt, the invention of the Marquis of Worcester." It is probable that the learned doctor was unacquainted with De Caus and Branca's previous experiments, or he could nót have come to this conclusion. But whilst we cannot admit the Marquis to be entitled to the extravagant encomiums which have been lavished upon him, we are far from disallowing his invention to possess merit and originality. The annexed drawing we consider to embody the Marquis's idea more perfectly than any we have seen, although there must be several parts unexplained.

The most difficult and unintelligible seems to have been the "forcing and refilling," which (but for its being a mechanical impossibility) one should imagine to mean that both these operations were going on at the same time, in the same vessel. The easiest way of getting over this difficulty seems to be by supposing the "refilling" to allude to the filling of the cistern, to which the water must be elevated. So that, instead of saying, "the other begins to force and refill," we should say, the other begins to force and *refill* the *cistern*. This, we confess, is a straining of the text, but at the same time much less so than Dr. Brewster's corrections, who reads: "One vessel of water being consumed, another begins to force, and then to fill itself with cold water;" or than the author of Stewart's History of the Steam Engine, who, in order to accommodate the text to *his* idea of the engine, makes an emendation by saying, "to force and *empty* of cold water."—The strengthening of a vessel by the force within, also appears to be a mechanical impossibility; but we conceive that, to an extent equal to any force required for raising water, a boiler, of the form represented in the figure, would be strengthened by the internal pressure.

The Marquis of Worcester's Engine, 1663.

In the above figure, *a* represents the boiler, composed of arched iron plates, with their convex sides turned inwards, they are fastened at the joinings by bolts passing through holes in their sides, which also pass through the ends of the rods *i i i.* A series of which rods extend from end to end of the boiler, being a few inches apart. The ends of this boiler are hemispherical, and are fastened to flanges on the plates *h h h h.* It will appear evident that, each plate being an arch, before the boiler can burst, several, if not nearly all the rods *i i*, must either be pulled asunder, or torn from the bolts at the points of junction; and as the strength of the rods and bolts may be increased to any extent, without interrupting the action of the fire, there can be no doubt but that a boiler might be so constructed as to be perfectly safe under any pressure, which could be required for raising water to a given height, because the

pressure in such a boiler will never exceed the weight of a column of water, equal in height to the elevation of the cistern.

b c represent two vessels, which communicate with the boiler *a*, by means of the pipes *f f*, and three-way cocks *m n*, and with the reservoir from which the water is to be drawn by the pipes *l l*. *g g* are two tubes, through which the water is elevated to the cistern; they reach nearly to the bottom of the vessels *b c*, and are open at each end. The pipe *l*, also *f f*, communicate with the vessels *b c*, by means of the three-way cocks *m n*, which, by moving the handles *o p*, can be so placed that either the steam from the boiler, or the water from the reservoir, shall instantly have access to the vessels *b c*.

Fire having been kindled under the boiler *a*, in the furnace *d*, "the man who tends the work" places the cock *n*, in the position represented in the drawing, when the water will have free access from the reservoir to the vessel *c*, which being filled, the handle *p* is turned back, so that the cock shall be relatively in the position shown at *m*; the steam then fairly enters through the pipe *f*, into the vessel *c*, and having no other mode of escape, presses on the surface of the water, which it forces up through the pipe *g*. During this operation, (the cock *m* having been placed as shewn at *n*,) the vessel *b* is filling from the reservoir through the pipe *l*; so that the water in the vessel *c*, being consumed, the man turns the handle *o*, of the cock *p*, and admits the steam on the surface of the water in *b*, shutting off, by the same operation, the communication between *b* and the reservoir; the other then begins to *repeat the act of filling the cistern*, "and so successively, the fire being tended and kept constant."

This apparatus, we submit, approaches nearer than any to the idea which we of the present day might form from the Marquis's description; but it should be observed, that, by such a modification, we may be giving him credit for arrangement to an extent which he himself never contemplated. In fact, though there can be no doubt but that he meant to describe a machine actuated by the force of steam, yet the absurdity of many of the remaining nine-

ty-nine of his projects and the ambiguity of this, warrant us to hazard a conjecture that he intended to gain his object by some arrangement of mechanism equally absurd with them. That his description is ambiguous and contradictory, none can deny; in fact, the strongest evidence of this, is the very different manner in which ingenious men have attempted to represent his machine.

But, whatever value may be set on the Marquis's merit as an inventor, we have not the slightest evidence of his having carried any of his projects into execution. In truth, judging by the character of the man, many have been led to question his title to their invention; for, according to Walpole, "He appears in a very different light in his public character, and in that of an author. In the former, he was an active zealot; and in the latter, a fantastic mechanic: in both, very credulous."—"We find him taking oath upon oath to the Pope's nuncio, with promises of unlimited obedience both to his holiness and to his delegate; and begging five hundred pounds of the Irish clergy, to enable him to embark and fetch fifty thousand pounds; like an alchymist who begs a trifle of money, for the secret of making gold;" —when, according to another author, "he had not a groat in his purse, or as much gunpowder as would scare a corbie."

About twenty years after this, (1682 and 1683), we find Sir Samuel Moreland, in France, endeavouring to promote a project for raising water by steam. His invention was exhibited to the French King, at St. Germains; but, unfortunately, no record remains of the experiment. An account of some of his experiments on the force of steam, however, is preserved among the Harleian Manuscripts* in the British Museum, which is evidently the result of great care, and exhibits much correctness in the calculations.

About the year 1680, Dr. Denys Papin, a native of Blois, commenced a series of experiments on the power of steam, which terminated in the construction of an useful and ingenious machine, a description of which we will speedily give. In 1684 he had discovered the method of dissolving bones by steam of a very high pressure and temperature, and in

* No. 5771.

this invention introduced that simple but inseparable accompaniment of every steam engine, THE SAFETY VALVE. This invention (without which steam would, long ere this, have been abandoned as a most dangerous and ungovernable agent,) entitles Papin to universal admiration; since it has contributed more than any single addition or improvement to the maturity of the steam engine.

The course of Papin's experiments occupied a number of years, and in their progress many ideas occurred to him, which have since been adopted as important improvements. His earliest project was that of using an air pump, for the purpose of transmitting power to some distance, in order to raise water where the first mover could not be conveniently applied. For instance, where a fall of water could be obtained, he proposed to erect a water wheel, which should work an air pump. This air pump he intended to connect by pipes with another pump at the place where the mine was situated. When by the crank on the water wheel the piston of one pump was depressed, the air in the pipes would be condensed, and force up the piston of the other cylinder; and when the piston of the first cylinder was elevated, that of the second would be drawn down by partial vacuum which the elevation produced. This experiment failed even in a model, owing to the great compressibility of the air, and Papin directed his studies to the discovery of some means of forming a vacuum under his piston. In 1688 he described a method of effecting this, by first displacing the air by exploding *gunpowder*. This he abandoned as dangerous; and, finally, after various experiments and failures, in 1690 he suggested the employment of *steam* for raising the piston, and afterwards forming a vacuum in the cylinder by its condensation. He states—"that in a little water, changed into steam by means of fire, we can have an elastic power like air; but that it totally disappears when chilled, and changes into water, by which means he perceived, that he could contrive a machine in such a manner that with a small fire he could be able, at a trifling expense, to have a perfect vacuum." After noticing the difficulty of making a vacuum by gun-

powder, he observes, "where there may not be the conveniency of a near river to turn the aforesaid engine, I propose alternately turning *a small surface* of water into vapour by fire, applied to the bottom of the cylinder which contains it: which vapour forces up the plug or piston in the cylinder to a considerable height, and which, as the water cools when taken from the fire, descends again by air's pressure, and is applied to raise water out of the mine."

This, as far as discovery goes, entitles Papin to the merit of having first invented the well-known Atmospheric Steam Engine: and, probably, had he followed up the idea by actual experiment, we would have had to record him as the man who first brought it into successful operation. But the greatest merit is not always due to the inventor; thousands of the most brilliant discoveries have perished for want of industry or talent to foster them. The man who first invents and afterwards struggles through every difficulty, and by the greatest sacrifices and perseverance brings it into actual practice, perhaps outsteps the projector of the most refined contrivance of which history can boast.

Whilst Papin was prosecuting these interesting experiments, a sea-faring man, named Thomas Savery, or, as he is commonly called, Captain Savery, was engaged in England, in endeavouring to bring into notice an engine of his invention, which possessed great merit. The description of his machine was published in a work of his, called "The Miner's Friend." This work is dated 1702, and contains, besides a candid detail of the principle, much useful instruction relative to the proper management of his machine. The liberality and honest appeal to experiment which pervades the whole work, forms a rare and striking contrast with the self-sufficiency and conceit which are too generally to be found in productions of this nature. Savery exhibited his model before King William, who warmly interested himself in the project. In June, 1699, he obtained a patent, granting him the exclusive privilege of manufacture. We subjoin a description nearly in the words of the inventor.

(*Savery's Patent Engine.* 1699.)

"The first thing is, to fix the engine in a good double furnace, so contrived that the flame of your fire may circulate round, and encompass your boilers, as you do coppers for brewing. Before you make any fire, unscrew G and N, being the two small *guage pipes* and cocks belonging to the two boilers, and at the holes fill L, the large boiler, two-thirds full of water, and D, the small boiler, quite full. Then screw on the said pipes again as fast and as tight as possible. Then light the fire at B, and, when the water in L boils, open the cock of the first vessel P (shown in section) which makes all the steam rising from the water in L pass with irresistible force through O into P, pushing out all the air before it through the clack R; and when all is gone out, the bottom of the vessel P will be very hot; then shut the cock of the pipe of this vessel, and open the cock of the other vessel P, until that vessel has discharged its air through the clack R up the force pipe S. In the mean time, by the *steam's condensing* in the vessel P, a vacuum, or emptiness, is created, so that the water from the well must and will necessarily rise up through the sucking pipe T, lifting up the clack M, and filling the vessel P.

"In the mean time, the first vessel P being emptied of

its air, open the cock again, and the force is upon the surface of the water, and presses with an elastic quality like air, still increasing in elasticity or spring till it counterpoises, or rather exceeds, the weight of the water ascending in S, the pipe, out of which the water in it will be immediately discharged when once gotten to the top, which takes up some time to recover that power; which having once got, and being in work, it is easy for one that never saw the engine, after half an hour's experience, to keep a constant stream running out the full bore of the pipe. On the outside of the vessel you may see how the water goes out, as well as if the vessel were transparent; for as far as the steam continues within the vessel, so far is the vessel dry without, and so very hot, as scarce to endure the least touch of the hand. But as far as the water is, the said vessel will be cold and wet where any water has fallen on it, which cold and moisture vanishes as fast as the steam in its descent takes place of the water; but if you force all the water out, the steam, or a small part thereof, going through P, will rattle the clack, so as to give sufficient notice to change the cocks, and the steam will then begin to force upon the other vessel without the least alteration in the stream, only sometimes the stream of water will be somewhat stronger than before, if you change the cocks before any considerable quantity of steam be gone up the clack R: but it is better to let none of the steam go off, for that is losing so much strength, and is easily prevented, by altering the cocks some little time before the vessel is emptied."

The ingenious inventor goes on to explain minutely the ease with which his engine could be managed; however, we have quoted sufficient to shew clearly the mode of operation. He gives no proportions of the parts, nor is it probable that he himself established any rule, but principally erected his engines by a kind of mechanical tact, which he possessed in a wonderful degree. He seems to have considered that the strength of his machine was the only limit to be observed; "for," says he, "I will raise you water 500 or 1000 feet high, could you find us a way

to procure strength enough for such an immense weight as a pillar of water of that height; but my engine, at 60, 70, or 80 feet, raises a full bore of water with much ease."

Captain Savery's invention shews him to have been a man of extraordinary talent and ingenuity. The real benefit which it conferred upon society was not alone confined to the reduction of animal labour: it had the effect of enabling ingenious mechanics to direct their energies to a subject which had hitherto been a matter of mere philosophical speculation. It furnished material for study; and, though it was adopted with caution, and to a very limited extent by the mining districts, there can be no doubt but it was the means of sowing those seeds of talent which have since enabled this country to outstep every other in the superior manufacture of steam machinery.

The honourable fame which the invention obtained him could not be enjoyed without detraction. Envious contemporaries were busily engaged in endeavouring to injure, by false accusation, the character which Savery obtained Desaguliers unequivocably asserts that Captain Savery merely put in practice the Marquis of Worcester's plan for raising water; and, the better to conceal the fact, bought up and burnt all the copies of Lord Worcester's Work on which he could lay his hands.

It has been very properly observed by Dr. Robinson, that such a charge ought to be substantiated by very distinct evidence. Now, as we have no evidence, excepting that of Dr. Desaguliers, we shall inquire as to the value which may be set on his. We shall go no further than quote his account of the origin of packing the piston of a steam engine. He states, that "having screwed a large broad piece of leather to the piston, which turned up the sides of the cylinder two or three inches, in working, it wore through, and cut that piece from the other, which, falling flat on the piston, wrought with its edge to the cylinder, and, having been in a long time, was worn very narrow; which being taken out, they had the happy discovery, whereby they found that a bridle rein, or *even* a soft thick piece of rope, going round, would make the piston air and water tight." On

which Hornblower remarks, that "we need not say any thing to the practical engineer about *leathering* a *steam* piston; nor is it necessary to comment on the Doctor's acquaintance with steam and leather in contact."

This extract we imagine will, by impugning the Doctor's veracity, completely set at rest the charge made against Captain Savery; but admitting, for the sake of argument, that he was even acquainted with the "Century of Inventions," we have already sufficiently shewn that it required a person to be intimately acquainted with the nature of steam, before he could even guess at the Marquis's project. All that could be gathered from his 68th article was, that water could somehow be raised by steam, by a certain undescribed arrangement of cocks, pipes, fire, and water. But we have, in Savery's Engine, a detail of the most perfect mechanism; besides which, it should be borne in mind that the Marquis states his engine does not operate by *sucking up the water*, whilst it is the essential requisite of Savery's apparatus.

We quitted Dr. Papin to detail the important results of Captain Savery's experiments, which were published in the interim between the commencement and conclusion of those of the ingenious Doctor, who, in 1698, we find still persevering in his project for raising water by steam, under the patronage of the Elector of Hesse. In 1705 he received from the celebrated philosopher, Leibnitz, (who had seen some of them in operation,) a drawing and description of Savery's engine. It is to be regretted that Papin ever received this communication, as it has been shewn that he had actually projected a plan, which, if carried into operation, would have constituted the Atmospheric Engine, invented by Newcomen. But, unfortunately, the success of Captain Savery diverted his mind from the superior project of forming a vacuum under a piston, and by the command of his patron, the elector, he set about to improve Savery's machine, which is universally allowed to be inferior in effect to the other. The talent of Papin, directed to the Atmospheric Engine, must have produced most important results, which, however, have been lost by the success of Captain Savery's machine.

The consequence of this course of experiment was the publication of a "New Method of raising Water by the force of Fire," dated at Cassel, 1707. He acknowledges that Savery had hit on another mode, without knowing his experiments. The following is a description of the machine.

A boiler *a*, made of copper, communicates by a pipe with a cylinder, *i*, which forms the body of the pump. This cylinder is attached to an upright pipe *o q*, which enters the cylinder *r r*, rising to within a short distance of its top. This latter cylinder is air tight, and has a pipe *w*, smaller in its bore than the pipe *o q*. The pipe between the boiler and cylinder has a stop cock at *c*. *f* is the safety valve which prevents the explosion of the boiler, by yielding to the force of the steam, and allowing it to escape when it exceeds a certain pressure, which is regulated by shifting the weight *f* on the lever. Within the cylinder is a piston or float, *n*, made of thin plates of metal, and loaded with the weight *h*, forming a part of a hollow cylinder, which floats on the surface of the water.

(*Dr. Papin's Engine.* 1707)

When a sufficient quantity of steam is generated in the boiler *a*, the cock is opened to allow it to flow into the pump cylinder *i*, forcing the water, which is beneath it, through the pipe *o q*, until it falls at the upper end *q*, into the receiver *r r*; since it cannot flow away through the pipe *w*, so rapidly as it comes in, on account of the pipe *w* being smaller, it rises and compresses the air into the upper part of the receiver. As it escapes through *w*, it issues with velocity on the water wheel *s*, to which it gives motion in the usual manner. When the floater *n* has reached the bottom of that cylinder, the cock *c* is shut, which prevents the further admission of steam from the boiler, into the pump cylinder, above the floater; and the valve *g* is lifted, to allow the steam above the floater to escape into the atmosphere; a vacuum speedily forms in this space, which is as speedily filled up by water from the mine, through the clack at the bottom of *i*; the clack *o* opening upwards, prevents the column of water in *o q* from descending, whilst the compressed air *r r*, keeps a constant stream on the wheel. When the floater has risen to its proper position, the steam is again admitted on the surface of the floater, and drives up the water as before.

This machine Papin published as the invention of the Elector of Hesse, but it is quite obvious that his disposition to flatter his patron, rather than the regard to truth, caused him to make this statement. We have already expressed our regret that Papin did not persevere in his idea of the *Atmospheric Engine*. As it is, he has shewn himself to be a man of great talent and originality.

It has been already observed that the beneficial effects of Savery's invention were not confined to the reduction of animal exertion. This, though a grand, was not the principal result which arose from its introduction; for the great danger, or more probably *fear*, of explosion, tended to counteract its general adoption. We say, therefore, that the greatest benefit which it created was that of familiarising all mechanics with the nature of steam; its elasticity when heated, and its *sucking power* when cooled; and when Savery's engine was found inadequate to the

proposed end, ingenuity was on the alert to apply these in some more efficient manner. This feeling found its way to the ancient town of Dartmouth, in Devonshire, and drew forth the attention of Thomas Newcomen, a blacksmith. This man, though possessed of little scientific knowledge, was endowed with a clear head, and great inventive powers. We are informed that he had seen one of Savery's engines, when he conceived the possibility of obtaining power in a manner similar to that proposed by Papin in his first project, namely, by a water-wheel working two air pumps. He was so completely convinced of the feasibility of his plan, that he applied to Dr. Hooke on the subject, who, it appears, dissuaded him from the prosecution, adding this remarkable suggestion, "If you could make a *speedy vacuum* in your second cylinder, your work is done."

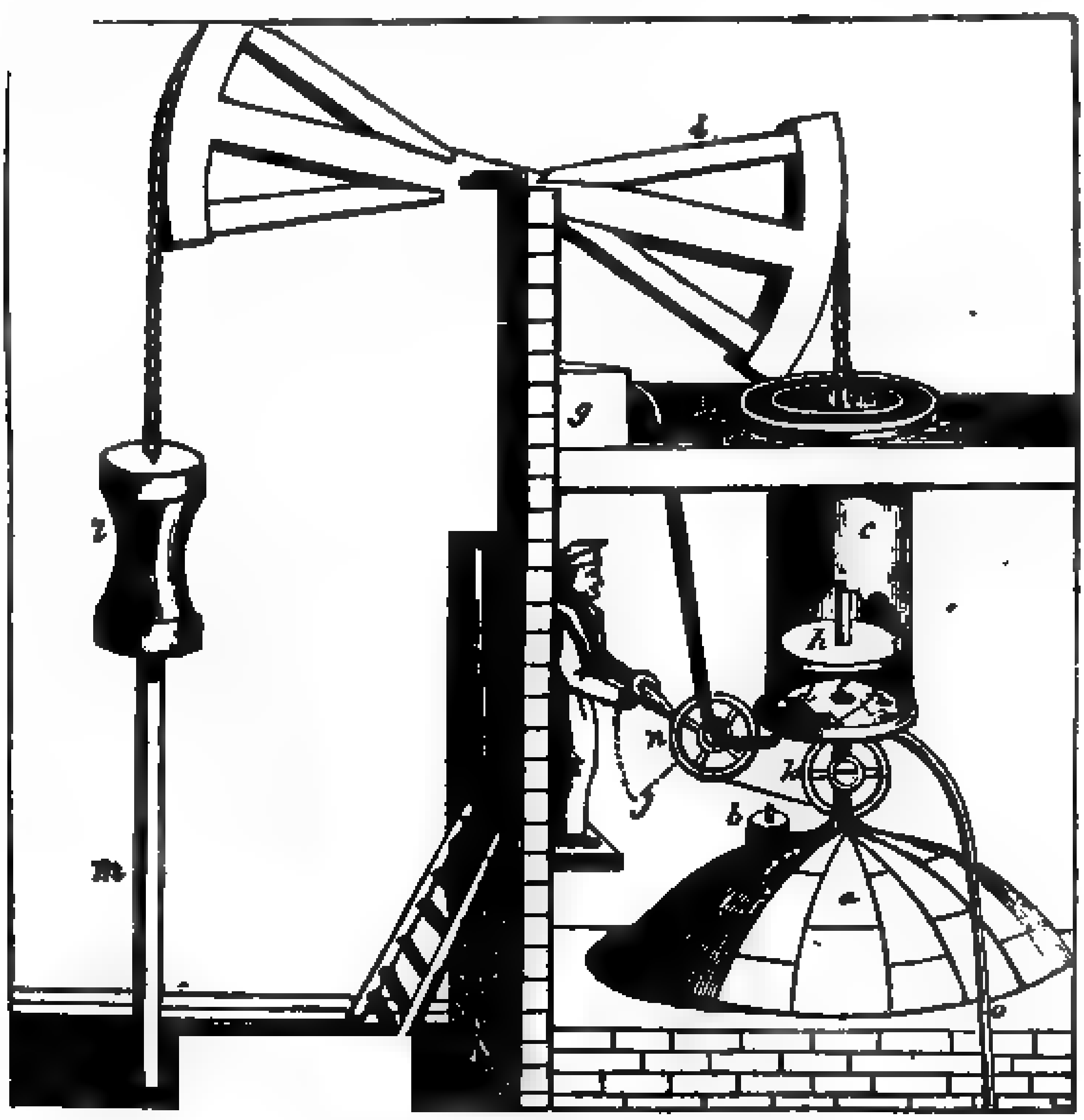
Newcomen, we are informed, was for some time engrossed with the new train of ideas to which this hint led him, till at length he conceived the power of *steam* would, in every respect, answer the end; and, according to Desaguliers, he communicated his project to his friend and associate, John Cawley, a glazier, with whom he made several private experiments in the year 1710, and in the latter end of the following year made proposals to drain a colliery at Griff, in Warwickshire, which had previously been drained by horses, in which work 500 were employed, at the expense of £900 a year; but the application not being received as they expected, in the March following they bargained to draw water for Mr. Back, of Wolverhampton, "where, after a great many laborious attempts, they succeeded in making the engine work."

To such of our readers as are unacquainted with the principle of the Newcomen engine in its simplest form, we recommend the following experiment:—Into the perforation of a small glass globe, partly filled with water, introduce the mouth of a common syringe. Form a luting round the joining, so as to render the joint good and tight. Apply this to the flame of a lamp, and, as soon as the water boils, the steam formed thereby will force up the rod of the syringe to the top: immerse the whole in cold water, and

the rod will as speedily descend. Apply the lamp again, and the rod will again be raised, and upon plunging it again into cold water it will descend as before; these motions may be repeated *ad infinitum*.

Newcomen and Cawley being assured of success, were about applying for a patent, when Savery claimed the invention as his, on the ground that the method of procuring a vacuum by steam was his discovery: they were, therefore, obliged to allow his name to be associated in the grant which they obtained in 1705.

We present our readers with a novel drawing of Newcomen's engine; we are not aware that such a machine was ever in operation, but as it represents some of the parts in a singular form, and shows clearly the mode of operation, we shall offer no apology for using it in our explanation.



(Newcomen's Patent Engine 1705.*)*

a represents the boiler, of which *b* is the safety valve, being a weight placed on a clack, which yields to steam above a certain pressure, and prevents explosion. *c* is the cylinder, open at the top, having three holes at the bottom, *d e f*. The hole *e* admits the steam from the boiler; the hole *d* admits a jet of cold water from the reservoir *g*, in order to expedite the condensation of the steam. *f* is a pipe for the exit of the condensed steam, and to get water from the cylinder. *h* is the piston or plunger, whose diameter exactly fills the area of the cylinder. It is packed or stuffed on its edge, so as to preserve the vacuum as perfect as possible: *i* is the beam, or (as it is called in some of the coal districts) the *loggerhead*, for the purpose of communicating the motion of the piston to the pumps in the mine.

A sufficient quantity of steam is first formed in the boiler, when the boy pushes the handle or lever which he holds down to *j*, which, by the wheels and band, opens the cock *k*, and allows the steam to enter the cylinder. The steam being only sufficient to equal the pressure of the atmosphere, will not of itself lift the piston and loggerhead; it is therefore necessary that some means should be adopted to aid it in its ascent. This is done by means of the weight or counterpoise *l*, so that by the force of the steam and gravity of the counterpoise, the piston is elevated to the top of the cylinder, and forces down the pump rod *m* into the pump in the mine. When this is effected, the boy returns the handle to its original position (shewn in the drawing) which prevents the admission of more steam from the boiler, and at the same time opens the cock *n*, so as to admit a small quantity of cold water from the reservoir *g* into the cylinder; this, by dispersing itself among the steam in the cylinder, almost instantly condenses it, so that a vacuum is obtained, and the pressure of the atmosphere meeting with no resistance, presses down the piston, and thereby raises the pump bucket in the mine. The handle is again depressed to *j*, which allows fresh steam to enter the cylinder, and elevate the piston as before. To prevent the accumulation of water

in the cylinder, the pipe *o* is of such length, that the weight of a column of water within it exceeds that of a column of the atmosphere, so that the water runs off by its own gravity.

The force of this engine, therefore, consists entirely of the pressure of the atmosphere, differing essentially from Papin and Savery, both of whom used the force of steam as well as a vacuum. By this method the danger of bursting the boiler was nearly obviated, as the pressure of one or two pounds on the inch on the boiler was sufficient to work the engine. The power must be regulated by the area of the piston, because, as the pressure of the air seldom exceeds 14¾ lbs. on an inch in a given area, we can never obtain more than a given power: thus, supposing the area to be 100 inches, and the pressure of the atmosphere 14 lbs. per inch, the pump piston would at each stroke lift 1400 lbs. of water at each stroke of the engine, a height equal to the length of the cylinder. This, however, is far above the real performance: as friction and imperfect condensation seldom leave more than one third of the power.

In the first engine of Newcomen, the steam was not condensed by an injection, but merely by surrounding the cylinder with cold water. Condensation by a jet is said to have been discovered from an accidental hole in the cylinder, allowing the water which surrounded it to get into the inside, and thus the speed of the engine was doubled. When the cause of this was ascertained, the injection cock was added, as a matter of course. We should also state, that the machine was by no means so simple as our drawing represents; a number of catches and springs being necessary to obtain the changes of the cocks; the uncertainty arising from the employment of boys was likewise a matter of much vexation and inconvenience. This evil, however, produced its own remedy; for a boy, named Humphrey Potter, being inclined to *scog*, or skulk, attached the lever which worked the valve to the beam by means of a cord and weight, by which addi-

tion the engine itself produced the necessary motion. This he called a "*scogger*."

With this addition, Newcomen's engine approached very nearly to a self-acting one; but still the turning of cocks and filling of reservoirs was obliged to be in part left to careless men, and as the precision of the work depended upon these, frequent derangement was the consequence; until Mr. Henry Beighton, of Newcastle-upon-Tyne, who was a mathematician, and conducted the Ladies' Diary, from 1714 to 1744, constructed what he called the hand gear, whereby motion was given to all the cocks and levers, by a rod from the beam. This engine was erected in 1718, and, besides the improvement mentioned, it was the first engine in which a *steel-yard* safety valve was used.

But to the celebrated Mr. Smeaton, more than any other person, except the inventor, were the public indebted for the perfection to which the Atmospheric Engine was brought. His experience in the construction of almost every kind of machinery aided him considerably in his various modifications of this. In constructing an engine for the New River Company, in 1767, he considered that the stoppage of the water at every stroke, as well as putting the lever beam, piston, heavy rods, and chains, from a state of rest into motion, twice at every stroke, was a great loss of power; he therefore determined to work the engine slower, and with large pumps, and put upon the piston all the load it would bear. To reduce the velocity of the column of water still more, he would place the fulcrum of the beam out of the centre, and make the stroke of the piston nine feet, whilst the pump which lifted thirty-six feet should work only a six feet stroke. This arrangement obliged him to employ a long narrow cylinder, of only eighteen inches diameter, and from this he also expected to obtain other advantages, *viz.* that every part of the steam, being nearer the surface of the cylinder, would be more readily condensed; and, in consequence, that a less quantity of injection water

would serve the cylinder, which would itself be more heated.

Under all these appearances of advantage, he ventured to burden the piston with a pressure of 10.4 lbs. per inch. Thus, area of piston (eighteen inches diameter) 254; weight of the column of water, thirty-six feet in the pumps, eighteen inches diameter, 3960 lbs.; of which take six-ninths for the difference of the length of stroke, and it gives 2640 lbs. for the weight to be lifted by the piston; and divide 2640 by 254, the area of the piston, gives 10.4 lbs. pressure per inch.

"Having once seen a common engine struggle under its burthen," says this ingenious engineer, "I thought myself quite secure under those advantages; but how great was my surprise and mortification, to find that, instead of requiring less injection water than common, although the injection pump was calculated to afford as much injection water as usual, in proportion to the area of the cylinder, with a sufficient overplus to answer all imaginable wants, it was unable to support the engine with injection, and that two men were obliged to assist to raise the injection water quicker, by hand, to keep the engine in motion; at the same time that the cylinder was so cold, I could keep my hand upon any part of it, and bear it for a length of time in the hot-well. By good fortune, the engine performed the work it was appointed to do, as to the raising of water, but the coals by no means answered my calculation. The injection pump being enlarged, the engine was in a state of doing business, and I tried many smaller experiments, but without any good effect, till I altered the fulcrum of the beam so much, as reduced the load upon the piston from 10½ lbs. to 8¼ lbs. per inch. Under this load, though it shortened the stroke at the pump end, the engine went so much quicker as not only to raise more water, but consume less coals; took less injection water; the cylinder became hot, and the injection water came out at 180° of Fahrenheit; and the engine, in every respect, not only did its work better, but went more pleasantly. This at once convinced me that a considerable degree of

condensation of the steam took place in entering the cylinder, and that I had lost more by this way, by the coldness of the cylinder, than I had gained by the increase of load. In short, this single alteration seemed to have unfettered the engine; but in what degree this condensation took place, under different circumstances of heat, and where to strike the medium, so as upon the whole to do best, was still unknown to me. But resolving, if possible, to make myself master of the subject, I immediately began to build a small fire-engine at home, that I could easily convert into different shapes for experiments, and which engine was set to work in the winter of 1769."

With this engine he tried various experiments, which he carefully recorded. He afterwards constructed several engines, which fully proved the correctness of his calculations. The first of these was at the colliery at Long Benton, near Newcastle-upon-Tyne, in 1774, which had a fifty-two inch cylinder.

The Atmospheric Engine represented in the Frontispiece to this Volume, contains most of the improvements of Mr. Smeaton. The boiler is omitted, and C represents the steam pipe, through which the steam passes from the boiler into the receiver.

D, the receiver, a close iron vessel, or box, in which is the regulator or steam cock, which opens and shuts the hole of communication with the cylinder at each stroke.

E is the communication pipe, between the receiver and the cylinder; it rises five or six inches up in the inside of the cylinder above the bottom, to prevent the injection water from descending into the receiver.

F, the cylinder of cast iron, about ten feet long, bored smooth in the inside; it has a broad flanch in the middle, on the outside, by which it is supported, when hung between the cylinder beams, which extend across the house, and are let into the side-wall.

G, the piston, made to fit the cylinder exactly, but with liberty to slide up and down; it has a flanch rising four or five inches upon its upper surface, between which and

the side of the cylinder a quantity of junk or oakum is stuffed, and kept down by weights, to prevent the entrance of air or water, and the escape of steam.

H, the chain and piston-shank, by which it is connected to the working beam by an arc of a circle.

I, I, the working beam, or lever, working on its centre, in the manner of a scale beam; it is made of two or more large logs of timber, bent together at each end, and kept at the distance of eight or nine inches from each other in the middle, by the gudgeon or centre, as represented in the plate. The arch heads I, I, at the ends of the beam, are for giving a perpendicular direction to the chains of the piston and pump-rods, which are suspended at the opposite ends.

N, the jack-head pump, which is a smaller sucking pump, wrought by a small lever or working beam, by means of a chain connected to the great beam or lever near the arch *g*, at the inner end; and the rod of the pump N is suspended by a chain at the outer end. This pump commonly stands near the corner or front of the house, and raises a column of water up to the cistern O, into which it is conducted by a trough.

O, the jack-head cistern, for supplying the injection; it is always kept full by the pump N, and is fixed so high above the cylinder bottom, as to give the jet of injection a sufficient velocity into the cylinder, when the cock is opened. This cistern has a waste-pipe on the opposite side for conveying away the superfluous water.

P, P, the injection pipe, of two or three inches diameter, which descends from the cistern O, to the injection cock *r*, after passing which it turns up in a curve at the lower end, and enters the cylinder bottom. It has a thin plate of iron screwed upon the end *d*, which is within the cylinder, with three or four ajutage holes in it, to cause the jet of cold water from the jack-head cistern to fly up in as many streams against the under surface of the piston, and condense the steam contained in the cylinder each stroke, when the injection cock is open.

e, a valve upon the upper end of the injection pipe,

which is shut, to prevent waste of water by leakage when the engine stands still; but before the engine is set to work this valve must be lifted up, and kept open by a string.

f, a small pipe which branches off from the injection pipe, and has a cock to supply the piston with a little water to keep it air tight.

Q, the working plug, suspended by a chain to the small arch *g*, of the working beam. It is usually a heavy piece of timber, with a slit vertically down its middle, and holes bored horizontally through it to receive pins, for the purpose of opening and shutting the injection and steam cocks, as it ascends and descends by the motion of the working beam.

h, the handle of the steam cock, or regulator. It is fixed to the regulator by a spindle, which comes through the top of the receiver. The regulator itself is a sectorial plate of brass, shaped like a fan, which is moved horizontally by the handle *h*, and opens or shuts the communication at the lower end of the pipe E, within the receiver.

i i, the spanner, which is a long rod or bar of iron, for communicating motion to the handle of the regulator, to which it is fixed by means of a slit in the latter, and some pins put through to fasten it.

k, *l*, the vibrating lever, called the tumbling-bob, or the Y, having the weight *k* at one end, and the two forked legs at the other end, like the letter λ turned. It is fixed to an horizontal axis, moveable about its centre pins or pivots *mn*, and is put in motion by means of two shanks, *o*, *p*, fixed to the same axis, which are alternately raised and depressed by means of two pins in the working plug, and the bob or weight at the top of the Y is thrown backwards and forwards; one pin on the outside, depressing the shank *o*, throws the loaded end *k* of the Y from the cylinder into the position represented in the drawing, and causes the leg, *l*, of the fork of the Y to strike against the end of the spanner, which forcing back the handle of the regulator, or steam cock, opens the communication, and permits the

steam to fly into the cylinder. The piston immediately rises by the weight of the pump rod, on the admission of the steam. The motion of the working beam, I, I, also raises the working plug; and another pin, which goes through the slit, raises the shank *p* of the axis, which throws the end, *k*, of the Y towards the cylinder, and the leg of the fork, striking the end of the spanner, forces it forwards, and shuts the regulator or steam cock.

q, *r*, is the lever for opening and shutting the injection cock, called the F. It has a rack or toothed sector fixed upon its axis, which takes the teeth of a pinion, fixed on the top of the plug, or key of the injection cock. When the working plug has ascended nearly to its greatest height, and shut the regulator, as above described, a pin catches the end *q* of the F, and raises it up, which opens the injection cock, and admits a jet of cold water to fly into the cylinder, and, condensing the steam, makes a vacuum within. Then the pressure of the atmosphere, forcing down the piston into the cylinder, causes the plug frame to descend, and another pin fixed in it catches the end of the lever *q*, in its descent, and by pressing it down shuts the injection cock, at the same time the regulator is opened to admit steam, and so on alternately; that when the regulator is shut, the injection cock shall be open, and when the former is open, the latter shall be shut.

R, the eduction pipe, to convey away the water which is injected into the cylinder at each stroke; its upper end is even with the cylinder bottom, and its lower end has a lid or cover, moveable on a hinge, which serves as a valve to let out the injection water, and shuts close each stroke of the engine, to prevent the water being forced up again, when the vacuum is made.

S, the hot well, which is a small cistern made of planks, to receive all the waste water from the cylinder, and keep it in reserve for feeding the boiler, to supply the waste occasioned by the continual evaporation of the steam.

T, the feeding pipe, to supply the boiler with water from the hot well. It has a cock to let in a large or small

quantity of water, as occasion requires, to make up for what is evaporated; it goes nearly down to the boiler bottom, so that the lower end is always immersed in water.

s, the snifting valve, by which, at every ascent of the piston, the air is discharged from the cylinder which was admitted with the injection, and would otherwise obstruct the due operation of the engine.

t, *t*, the cylinder beams, which are strong girdles going through the house, for supporting or rather keeping down the cylinder.

v, the cylinder cup of lead surrounding the top of the cylinder, to prevent the water upon the piston from flashing over, when it rises too high.

W, the waste pipe, which conducts the superfluous water from the top of the cylinder to the hot well.

x, iron bars, called the catch pins, fixed horizontally through each arch head, to strike the floor, and prevent the beam descending too low, in case the chains at either end should break, or if the engine make too long a stroke.

y, *y*, two strong wooden springs, to weaken the blow given by the catch pins when the stroke is too long.

z, *z*, two friction wheels, or sectors, on which the gudgeons, or centres of the great beam, are supported; they are the third or fourth part of a circle, and move a little each way, as the beam vibrates. Their use is to diminish the friction of the axis, which being necessarily very large for so heavy a lever, would otherwise be very great.

When this engine is to be set to work, the boiler must be filled about two or three feet deep with water, and a large fire made under it; and when the steam is heated to be of sufficient strength to exert a pressure of about one pound beneath each square inch of the safety valve, it will lift up the valve and escape. The water in the boiler being supposed to be in a strong state of ebullition, and the steam issuing by the safety valve, we will consider the machine in a state of rest, having both the steam cock and injection cock shut. The resting position or attitude of the machine is such as appears in the drawing, the pump

rods, K, preponderating by their weight, and the great piston being drawn to the top of the cylinder.

The man that attends the engine depresses the handle *p*, so as to throw the tumbling bob into the position of the figure; and the leg of the fork thrusting back the spanner *i*, *i*, opens the regulator, or steam cock, when the steam from the boiler immediately rushes in, and flying all over the cylinder, will mix with the air; much will be condensed by the cold surface of the cylinder and piston, and the water produced from it will trickle down the sides, and run off at the eduction pipe R, as soon as any quantity is accumulated. This condensation and waste of steam will continue, till the whole cylinder and piston are made as hot as boiling water.

When this happens, the steam will begin to open the snifting valve *s*, and issue through the pipe; at first, slowly and very cloudy, being mixed with much air, the cloudy appearance of steam being always owing to its mixture with common air. The blast at *s* will grow stronger by degrees, and more transparent, having already carried off the greatest part of the common air which filled the cylinder. We supposed, at first, that the water was boiling briskly, so that the steam was issuing by the safety valve, which is in the top of the boiler. The opening of the steam cock puts an end to this at once, because the cold cylinder draws off the steam from the boiler with astonishing rapidity, until it becomes heated so as not to condense.

When the manager of the engine perceives that not only the blast at the snifting valve is strong and steady, but that the boiler is fully supplied with steam of a proper strength, which appears by the renewal of the discharge at the safety-valve, the engine is ready for starting. He now lifts up the handle *o*, or *p*, till the tumbling bob, Y, falls over the perpendicular towards the cylinder, and its leg striking the cross-pin of the spanner *i*, draws it forwards, and shuts the steam regulator; at the same instant he lifts up the handle, *q*, of the F, which opens the injection cock. The pressure of the column of water in the

injection pipe, P, immediately forces some water through the spout *d*, by the jets.

The cold water coming in contact with some of the pure vapour, which now fills the cylinder, condenses it, and thus makes a partial void, into which the more distant steam immediately expands; and by this very expansion its capacity for heat is increased; or, in other words, as it grows cold, it abstracts the heat more powerfully from the steam situated immediately beyond it.

In this expansion and refrigeration, the steam is itself partly condensed or converted into water, and leaves a void, into which the circumjacent steam immediately expands, and produces the same effect on the steam beyond it; and thus it happens, that the abstraction of a small quantity of heat from an inconsiderable mass of steam, produces a condensation throughout a cylinder which is very extensive.

What remains in the cylinder no longer balances the atmospheric pressure on the surface of the water in the injection cistern, and therefore the water spouts rapidly through the holes *d*, by the joint action of the column P, and the unbalanced pressure of the atmosphere; at the same time the snifting valve *s*, and the eduction valve R, are shut by the external pressure of the atmosphere, and prevent the entrance of air or water into the cylinder.

The velocity of the injection water must therefore rapidly increase, and the jets dash against the bottom of the piston, and be scattered through the whole capacity of the cylinder. In a very short space of time therefrom, the condensation of the steam becomes universal, and the elasticity of what remains is very small. The whole pressure of the atmosphere, therefore, being exerted on the upper surface of the piston, while there is hardly any on its under side, if the load on the outer end of the working beam is inferior to this pressure, it must yield to it. The piston G must descend, and the pump piston, *k*, must ascend, bringing along with it the water of the mine; but the motion does not begin at the instant the injection is made. The piston was kept at the top by the preponde-

rancy of the outer end of the working beam, and the load of water in the pumps; and it must remain there, till the difference between the elasticity of the steam below it, and the pressure of the atmosphere, exceed this preponderancy. There must, therefore, be a small space of time between the beginning of the condensation and the beginning of the motion; this is very small, not exceeding the third or fourth part of a second, but it may be very distinctly observed by an attentive spectator, who may perceive that, the instant the injection cock is opened, if the cylinder has the slightest yielding in its suspension, it will heave upwards a little by the pressure of the air on the bottom. Its own weight is not at all equal to this pressure; and, instead of its being necessary to support it by a strong floor, it must be kept down by large beams, loaded at the end with heavy walls. This heaving of the cylinder shows the instantaneous commencement of the condensation; and it is not till after this has passed, that the piston is seen to start, and begins to descend.

The motion must continue till the great piston reaches the bottom of the cylinder, because it is not like the motion which would take place in a cylinder of air rarefied to the same degree. In this latter case, the impelling force would be continually diminished, because the capacity of the cylinder diminishing by the descent of the piston, the air in it would continually become more dense and elastic, until the piston would stop at a certain height, when the elasticity of the included air, together with the load at K, would balance the atmospherical pressure on the piston. But when the contents of the cylinder are pure vapour, and the continued stream of injected cold water keeps down its temperature to the same pitch as at the beginning, the elasticity of the remaining steam can never increase by the descent of the piston, nor exceed what corresponds to the temperature according to our table. The impelling, or accelerating force, therefore, remains the same, and the descent of the piston will be accelerated almost uniformly, unless there is an increase of resistance, arising from the nature of the work per-

formed by the other end of the beam. And it may be frequently observed in a good steam engine, where every part is air-tight, that if the cylinder has been completely purged of common air before the steam cock is shut, and if none has entered since, the piston will descend to the very bottom of the cylinder. It sometimes happens, by the great pump drawing air, or some part of the communication chains giving way, that the piston descends with such violence as to beat out the bottom of the cylinder with the blow, and it is to prevent this accident that the catchpins are applied at the end of the beam.

When the manager sees the piston as low as he thinks proper, he shuts the injection cock, by depressing the lever *q*, and at the same time he opens the regulator, by forcing down the handle *o*, which oversets the tumbling bob, and its leg catching the cross pin of the spanner *i*, opens the regulator.

The steam has been accumulating above the water in the boiler, during the whole time of the piston's descent. The moment, therefore, that the steam cock is opened, the steam, having an elasticity of rather more than one pound per square inch greater than that of the air, rushes into the cylinder, when it immediately blows open the snifting valve, and assists the water which had come in by the former injection, and what arose from the condensed steam, to descend by its own weight through the eduction pipe S, and open the valve to run into the hot well R.

This water is nearly boiling hot, or at least its surface; for while lying in the bottom of the cylinder, it will condense steam till it acquires this temperature, and therefore cannot run down till it will condense no more. There is a cause of some waste of steam at its first admission, in order to heat the inside of the cylinder, and the injected water, to the boiling temperature; but the space being small, and the whole being already very warm, it is soon done; and when things are properly constructed, little more is wanted than what will warm the cylinder; for the eduction pipe is made of large dimensions, and receives some of the injection water even during the descent of the

piston, and this portion will be removed out of the way of the steam.

The first effect of the entering steam is of great service; it drives out of the cylinder the vapour which it finds there. This is seldom pure steam, or watery vapour, because all water contains a quantity of air, in a state of chemical union; but the union is only feeble, and a boiling heat is sufficient for disengaging the greatest part of it, by increasing its elasticity. It may be also disengaged by simply removing the external pressure of the atmosphere; this is clearly seen, when we expose a glass of water in an exhausted receiver. Therefore the small space below the piston contains watery vapour, mixed with all the air which had been disengaged from the water in the boiler by ebullition, and all that was separated from the injection water by the diminution of external pressure, in addition to any which may enter by leakage.

Let us now consider the state of the piston, when setting out on its return, as it is evident that it will start, or begin to rise by the counterweight, the moment the steam cock is opened; for at that instant the excess of atmospherical pressure by which it was kept down, in opposition to the preponderancy of the outer end of the beam, is diminished. At the first instant of the return of the pump rods, they draw up the piston with great violence, all the weight of the water in the pumps acting in addition to the counterweight; but the falling of the lower valves in the pumps, after an inch or two of motion, arrests the farther descent of the water, and bears the weight of the column of water, and after this the piston will rise gradually by the action of the counterweight.

The action of the counterweight is very different in the two motions of the engine; for while the engine is making a working stroke, it is lifting not only the column of water in the pump, but the absolute weight of the bucket rods also; and while the pump rods are descending, there is a diminution of the counterweight by the whole weight lost by the immersion of the rod in water. The wooden rods which are generally used, by being soaked in water and

joined by iron straps, are heavier, and but a little heavier than water; they are generally about one-third of the bulk of the water in the pumps. By this counterweight the piston is drawn upwards, and it would even rise, although the steam which is admitted was not quite so elastic as common air.

Suppose the mercury in the barometer to stand at 30 inches, and that the preponderancy at the outer end of the beam was equal to $\frac{1}{8}$th of the pressure of the air on the piston, the piston would not rise until the elasticity of the steam was equal to $30-\frac{1}{8}$, that is, $26\frac{1}{4}$ inches nearly; but if the steam was just equal to this quantity, the piston would rise as fast as the steam of that density could be supplied to the cylinder through the steam pipe; and on this supposition the velocity of the ascent would depend on the velocity of that supply. But this is not the case in practice, because the steam must be stronger than the air, in order to blow out and discharge the air; it will therefore enter the cylinder without any effort of the piston to draw or suck it in. At the same time the counterweight must not be so great as to draw up the piston with that force which will cause a suction within the cylinder greater than the steam pipe can supply, or it would diminish the pressure of the steam within the cylinder lower than the atmosphere, and prevent it from snifting or blowing out the air.

In filling the cylinder with steam, it will require a much more copious supply of steam than merely to fill up the space left by the ascent of the piston; for as the descent of the piston was only in consequence of the vacuum occasioned by the interior of the cylinder being sufficiently cooled to condense the steam, this cooled surface must be again presented to the steam during the rise of the piston, and must condense steam a second time. The piston cannot rise another inch, till that part of the cylinder which the piston has already quitted has been warmed up to the boiling point, and much must be expended in this warming; for the inner surface of the cylinder must not only be raised to the heat of boiling

water while the piston rises, but must also be made perfectly dry, and the film of water left on it by the ascending piston must be completely evaporated, otherwise it will continue to condense steam.

On this account, although the counterweight is not necessary to suck in the steam, the moving force during the ascent of the piston must be considered as resulting chiefly, if not solely, from the preponderating weight of the great pump rods; and this force is expended partly in returning the steam piston to the top of the cylinder, where it would be again pressed down by the air, and make another working stroke. This latter requires force independent of the friction inertia of the moving parts, for each bucket must be pushed down through the water in the barrel, which must lift up and rise through the valves in the bucket with a velocity proportioned to the velocity of the bucket, in the same degree as the area of the pump barrel is proportioned to the opening of the valves through which the water must pass.

From this general consideration of the ascent of the piston, we may see that the motion differs greatly from the descent; it can hardly be supposed to accelerate it, even if the steam were supplied to the cylinder in ever such quantity; for the resistance to the descent of the pump bucket is the same with the weight of the column of water, which could cause water to flow through the valves of the buckets with the velocity with which it really rises through them; and this resistance must therefore increase as the square of that velocity increases; that is, as the square of the velocity with which the bucket descends. Independent of the force of friction and the weight of the valves, the velocity of descent through the water must soon become a maximum, and the motion will become uniform. Accordingly, any one, who observes with attention the working of a steam engine, will see that the rise of the piston and descent of the pump rods are extremely uniform, whereas the working stroke is very sensibly accelerated.

These two motions complete the period of the operation,

and the whole may be repeated by shutting the regulator, and opening the injection cock, whenever the piston has attained the proper height. For the first two or three strokes, the opening and shutting of the cocks are performed by the attendant; but when he has thus ascertained that all parts are in order, he puts the pins into the holes of the plug frame, and the motion of the engine will then actuate its own machinery, and perform its reciprocations with greater regularity than can be done by hand.

In the year 1720, Leupold, the author of "*Theatrum Machinarum*" constructed *the first high-pressure engine*. Previous to this, the only use to which steam had been *effectively* applied was in the formation of a vacuum: true it is, that in the projects of De Caus, Branca, and Savery the elastic force of steam was proposed to be used; but the failure of these plans, by waste of steam and other causes, warrant our saying that the plan of Leupold entitles him to the great merit of having *invented and constructed the first high-pressure engine*. His principle was simply that of applying highly elastic steam alternately upon two pistons in separate cylinders, so that as one ascended the other descended, and *vice versa*.

In the annexed figure (nearly resembling that given by Leupold) the boiler, *a*, communicates, by a "*four-way cock*," with the bottom of two *open topped* cylinders, having pistons, *c*, *d*, moving in them. These pistons are fitted with lead, so that they may act as a counterpoise to the pump buckets *o p*. They are likewise attached to the beams *g h*, by means of the rods *e f*. To the other ends of the beams are fixed the pump rods *k l*, which work two force pumps *o p*. *q* is a perpendicular pipe, bended round at the top, so as to convey the water driven up the pipe into the cistern or spout *t*. *i i* are the centres of the two beams *g h*. *x* is a cock so constructed as to alternately admit the steam into either cylinder.

In the situation of the machine shewn in the figure, the steam in the boiler flows through the open passage into the cylinder *r*, and presses the piston *c* upwards: this depresses the pump rod *k*, and forces the water under the plunger, up the pipe *q*. When the steam has raised the piston *c* to nearly the top of the cylinder, the cock *x* is turned one fourth of a revolution, so that it opens a passage between the cylinder *s*, and the boiler; and between the cylinder *r*, and the open air. The weight of the rod *f*, and the lead in the piston *c*, being greater than *k* and *o*, the piston descends by its gravity to the bottom of the cylinder, driving out the steam which raised it into the atmosphere. From the construction of the "*four-way cock*," at the moment in which the passage into the cylinder *r* was closed, another passage was opened between the boiler and cylinder *s*; the elasticity of the steam forces the piston *d* upwards, and depresses the plúnger at the end of the rod *l*, and impels the water, in the barrel *p* under it, up the pipe *q*. When the piston *d* has reached the top of the cylinder, or made its stroke, the farther passage of steam from the boiler is shut off, by turning the cock *x*; and the steam escapes into the atmosphere through *z*; and *d* descends in the cylinder by its preponderance in the same manner as *c*. During the ascent of *d*, *c* has fallen to the bottom of the cylinder *r*. The steam passage from the boiler being then opened, *c* is again raised in its cylinder, while the vapour in *s* is escaping into the atmosphere; thus producing an alternate vertical motion in the pump rods *k l*.

(Leupold's Engine. 1720.)

Such was the construction of the first high-pressure engine, which for simplicity has never been exceeded. The extended use of such engines at the present day, proves that the public opinion is materially changed in regard to their utility and safety. The risk of explosion was a drawback upon them, which successive improvements and skilful management have almost annihilated; and we have no doubt but that, eventually, the low-pressure or condensing engine will be entirely abandoned in their favour. Their superior economy, by reduced consumption of fuel, and reduced friction, is sufficient ground for

their general adoption. We should observe, however, that there is still a mass of prejudice to contend with, ere this can possibly take place; and whilst America has scarcely a low-pressure engine to work a steam boat, it would be a hazardous speculation to attempt the introduction of a high-pressure one in England for that purpose.

But, from the importance which the latter does, and will maintain, in the mechanical world, it will not be amiss to shew the advantages which it possesses; and we will first speak of that obtained by a saving of fuel.

Water does not boil under a temperature of 212° of Fahrenheit, at which temperature its force, when confined, is barely equal to that of the atmosphere. But let the temperature be increased only 38° more, (which can be effected with a comparatively small addition of fuel,) and its force will be 28 lbs. on the square inch. In like manner let the temperature be increased to 280°, and the force will be equal to 56 lbs. Thus, the increased force far exceeds the increased consumption of fuel, and, consequently, the greater the pressure of the steam, the greater will be the saving. Recent experiments have proved that steam, when heated to 1170°, will act with a force of 56,000 lbs. on the square inch; so that we find 250° gives a force of only 28 lbs. whilst rather more than four times that temperature, or 1170°, gives 2000 times the force; a fact sufficiently establishing the superior economy of high-pressure steam.

It should be observed, however, that we by no means believe that such pressure can be used with safety; but we merely state the fact to establish the position that high-pressure engines are more economical than low-pressure ones.

The saving of power, by reduced friction, is also another material advantage in the former, because it is evident that if a force of 50 lbs. be obtained per square inch, for 10 or 12 in the condensing plan, the area of the piston will be smaller in the same proportion as the force is increased, in order to produce a given effect; therefore, the edges of

the piston being reduced also, there will be less rubbing surface than in the other.

Hitherto, steam had been only employed in raising water, nor had any plan been devised by which it could be adapted to imparting motion to machinery; Savery, indeed, says his machine might be applied "to mills of various kinds and forms, according to the different genius and abilities of the millwright;" and that "it may be brought to work by a steady stream," (on a wheel), "and produce a rotatory or circular motion;" and hints, that it might be made very useful in ships, but he dare not meddle with that matter; and leaves it to "the judgment of those who are the best judges of *maritian* affairs;" but since Savery's machine itself failed, of course the projects perished with it. After the important improvements of Newcomen, it will appear evident that any effectual method must be very different from this; and, accordingly, we find a patent taken out in 1736, by Mr. Jonathan Hulls, of London, "For a new-invented machine for carrying vessels or ships out or into any harbour, port, or river, against wind or tide, or in a calm." This new method was the application of the crank, which now, it is well known, enables us to employ the steam engine as a prime mover in almost every species of machinery.

Unfortunately, the public mind was not sufficiently matured to interest itself in the project; and, in consequence, Hulls and his patent were so completely forgotten, that the invention has been subsequently claimed by Mr. Watt.

We should here observe, however, that whilst we give due praise to Hulls for the greatness of his project, we feel satisfied that Newcomen's engine was not at all adapted to the proposed combination; as the great difference in power between the ascending and descending stroke of the piston would have required a ponderous fly wheel to have any thing like equality of motion, and a fly wheel would be an inconvenient accompaniment to a steam boat. The idea, however, was great, and the ingenious inventor deserved better success than he obtained.

We should not omit in this place to notice Blakey's patent, in 1766, for improvements on Savery's method of raising water. To avoid condensation, he proposed to introduce oil on the surface of the water, because oil did not so readily absorb the caloric; but his principal improvement consisted in the boiler, which was formed of small tubes, completely filled with water. The proposed improvements drew forth the attention of almost all the scientific men of his day, many of whom declared it possible to conduct the influence of steam to the centre of the earth. "But," says Hornblower, "an accident terminated the event as to the experimental engine, by one of the steam vessels bursting through the force of steam, though much under the degree of power proposed by the Cornish gentlemen. Such," continues Hornblower, "is the degeneracy of man, that whilst the States General of Holland were pluming Blakey with the gaudiest expressions of approbation, not one instance is to be found, in which he met with that support he had been led to expect."

(Blakey's Patent Boiler.)

a represents the furnace in which the tubes, *b c d*, are placed, which are connected by small pipes; *f* is a funnel for supplying the generator with water. This was the ancient mode of supplying all boilers, but it is needless to observe, that since the addition of the force pump, the former has been unnecessary. *e* is a cock, for the purpose of cleaning the boiler, by running water through the whole. The pipe which connects the generator with the engine is not shown.

Mr. Keane Fitzgerald, a gentleman of great scientific acquirements, and whose ingenious discoveries stand recorded in the Philosophical Transactions, describes, in the year 1758, an invention, by which he proposed to obtain a rotatory motion from a rectilineal one, in another way than by the crank, the application of which was unknown to him. No drawing has ever been given, and we therefore give the accompanying sketch, which we gather from the words of the inventor: they are as follow—

"A rotatory motion may be obtained from a rectilineal one, by employing a combination of large toothed wheels, and of smaller ratchet wheels, worked by teeth upon the arch or sector of the beam, one of these ratchet wheels being put in motion by the ascent of the beam, and standing still during the descent, when another ratchet wheel is moved by an intervening wheel in the same direction as the first; and thus the two communicate a continuous rotatory motion to the axis upon which they are placed, which is thence transmitted by a large toothed wheel to a smaller wheel or pinion, on the shaft of which is *a fly to accumulate momentum*, and crank proposed to be applied to work ventilators, and to many other useful purposes. The fly, by accumulating in itself the power of the machine during the time it was acted upon, would continue in motion, and urge forward the machinery, whilst the steam engine was going through its inactive returning stroke."

Let *a*, then, represent the cylinder on the principle of Newcomen; *b c*, two racks, of which *c* is the piston rod; these racks are toothed on two angles, two for the purpose of being moved by, and giving motion to the connecting pinion *d*, and the remaining two for the purpose of working the sectors, *e f*; these sectors have palls or catches fixed on each of them, which are situated so as to fall into the teeth of the ratchets, *g h*.

(*Fitzgerald's Motion.* 1758.)

We will now suppose the piston rod or rack, *c*, to be ascending: then the catch on the arm of the sector will turn round the ratchet, and the axle upon which it is fixed, a portion of a revolution. This motion will be continued until the piston has reached the top, when the pall of the sector, *f*, falls into the next tooth of the ratchet. The motion of the piston is now reversed; but by the intervention of the pinion *d*, the rack *b* begins to ascend, and repeats the same operation upon the ratchet *g*, as the other sector did upon *h*: thus, the two sectors alternately act upon the ratchets, and keep the axle in a continuous rotatory motion; this motion is communicated to another axle by the wheels *i j*: on the latter axis a fly is fixed, which preserves the motion equable and regular.

There is much ingenuity in this invention, although we are satisfied it would never answer the proposed end. The principal objection would be that of the piston striking violently the top and bottom of the cylinder; because, as the motion of the fly is obtained from the direct action of the piston rod, any decrease of speed in that must likewise decrease the speed of the fly-wheel, and therefore produce an irregular motion. Not so the common crank, which naturally retards the motion of the piston, as it approaches the top and bottom of the cylinder, whilst itself revolves at the same speed throughout.

We now come to the most important era in our history: that in which Mr. James Watt commenced his invaluable exertions in the improvement of the Steam Engine. It belongs not to our plan to give biographical sketches of the inventors who come under our notice; but as the beginning and progress of Watt's career form some of the principal events of his life, our History must here assume somewhat of this character.

James Watt was born in Greenock, in the year 1736. He was, at the age of sixteen, apprenticed to a mathematical instrument maker. This business, it appears, differed materially from what we now understand by the term, as it consisted of land-surveying, making and repairing clocks, almost every kind of musical instruments, fishing-tackle,

and cutlery. In the year 1757, he was appointed mathematical instrument maker to the University of Glasgow, and apartments were assigned to him in the College, in which he lived and transacted his business.

It appears that at this period, the College of Glasgow possessed apparatus and funds by which they were enabled to contribute largely to the general diffusion of useful knowledge among that class of individuals to whom it was peculiarly beneficial. This was one among the many advantages which arose from the establishment; but the greatest was that of exciting the attention, and drawing forth the energies of young Watt. We shall give the particulars of the commencement of his career in his own words, being satisfied that we cannot exceed them either in simplicity or effect.

"My attention," says he, "was first directed, in 1759, to the subject of steam engines, by Dr. Robison, then a student in the University of Glasgow, and nearly of my own age. Robison at that time threw out the idea of applying the power of the steam engine to the moving of wheel carriages, and to other purposes; but the scheme was not matured, and was soon abandoned on his going abroad.

"In 1761, or 1762, I made some experiments on the force of steam in a Papin's digester, and formed a species of steam engine, by fixing upon it a syringe one third of an inch in diameter, with a solid piston, and furnished also with a cock to admit the steam from the digester, or shut it off at pleasure, as well as to open a communication from the inside of the syringe to the open air, by which the steam contained in the syringe might escape. When the communication between the cylinder and digester was opened, the steam entered the syringe, and, by its action upon the piston, raised a considerable weight (fifteen pounds) with which it was loaded. When this was raised as high as was thought proper, the communication with the digester was shut, and that with the atmosphere opened; the steam then made its escape, and the weight descended The operations were repeated, and, though

in this experiment the cock was turned by hand, it was easy to see how it could be done by the machine itself, and make it work with perfect regularity. But I soon relinquished the idea of constructing an engine upon this principle, from being sensible it would be liable to some of the objections against Savery's engine; namely, from the danger of bursting the boiler, and the difficulty of making the joints tight; and also that a great part of the power of the steam would be lost, because no vacuum was formed to assist the descent of the piston."*

The attention necessary to his business of a mathematical instrument maker, prevented him from prosecuting the subject any further at this time. But in the year of 1763-4, having occasion to repair a model of Newcomen's engine, belonging to the Natural Philosophy Class of the University, his mind was again directed to the subject. At this period his knowledge was derived principally from Desaguliers, and partly from Belidor. He set about repairing the model *as a mere mechanician*, and when that was done and set to work, he was surprised that its boiler was not supplied with steam, though apparently quite large enough (the cylinder of the model being two inches in diameter and six inches stroke, and the boiler about nine inches in diameter); by blowing the fire it was made to take a few strokes, but required an enormous quantity of injection water, though it was very lightly loaded by the column of water in the pump. It soon occurred to him that this was caused by the little cylinder exposing a greater surface to condense the steam than the cylinders of larger engines did, in proportion to their respective contents; and it was found that by shortening the column of water, the boiler could supply the cylinder with steam, and the engine would work regularly with a moderate quantity of injection. It now appeared that the

* The reasons here given by the historian will appear, to modern mechanics, very futile and insufficient. It is not a matter now of *any* "difficulty to make the joints tight;" and high-pressure steam, it is well known, is more economical than that with which Mr. Watt worked his engines.

cylinders being of brass would conduct heat much better than the cast-iron cylinders of larger engines (which were generally lined with a strong crust), and that considerable advantage could be gained, by making the cylinders of some substance that would receive and give out heat the slowest.* A small cylinder, of six inches diameter and twelve inches stroke, was constructed of wood, previously soaked in linseed oil, and baked to dryness. Some experiments were made with it; but it was found that cylinders of wood were not at all likely to prove durable, and that the steam which was condensed in filling it, still exceeded the proportion of that, which was required in engines of larger dimensions. It was also ascertained, that unless the temperature of the cylinder itself were reduced as low as that of the vacuum, it would produce vapour of a temperature sufficient to resist part of the pressure of the atmosphere. All attempts, therefore, to reduce by a better exhaustion, by throwing in a greater quantity of injection water, was a waste of steam; for the larger mass of injected water cooled the cylinder so much, as to require a quantity of steam to heat it again, out of proportion to the power gained by having made a more perfect vacuum; and on this account the old engineers acted wisely in loading the engine with only six or seven pounds weight on each square inch of the piston.

It appears by Dr. Ure, that Watt tried some experiments regarding the latent heat of steam, of which the Doctor gives the following account:—"In some conversations with which this great ornament and benefactor of his country honoured me, a short period before his death, he described, with delightful *naïveté*, the simple but decisive experiments by which he discovered the latent heat of

* The inventor was right in proposing to use some material which would receive and give out heat the slowest, but greatly in error when he supposed *polished surfaces* would conduct heat quicker than rough ones. It has been repeatedly proved, that rough surfaces are best adapted to give out or receive heat, the unevenness of the surfaces acting like an immense number of conductors to and from the metal.

steam. His means and leisure not then permitting an expensive and complete apparatus, he used apothecaries' phials. With these, he ascertained the two main facts; first, that a cubic inch of water would form about a cubic foot of ordinary steam, or 1728 inches; and that the condensation of that quantity of steam would heat six cubic inches of water, from the atmospheric pressure to the boiling point. Hence he saw that six times the difference of temperature, or fully 800° of heat, had been employed in giving elasticity to steam, and which must be all subtracted before a complete vacuum could be obtained under the piston of a steam engine."

The great experimentalist deserves as much praise for these experiments as for any thing he ever effected. Upon the facts developed in this inquiry, he constructed the theory which will carry his name to posterity. Although he modestly ascribes his discovery to Dr. Black's explanation of his *theory of latent heat*, there can be no doubt that these experiments were more decisive and useful than any theoretical explanation could possibly be.

He found, therefore, that his first business was to keep the cylinder as hot as possible, and that to obtain a tolerable vacuum, the temperature of the condensed steam should be at most 100°, and less if possible. Various were the means which were contemplated to effect these ends, when, early in 1765, it struck him, "*that if a communication were opened between a cylinder containing steam, and another vessel which was exhausted of air and other fluids, the steam, as an expansible fluid, would immediately rush into the empty vessel, and continue to do so until it had established an equilibrium; and if that vessel were kept very cool, by an injection or otherwise, more steam would continue to enter until the whole were condensed.*"

So far we have the invention complete; but still the condensed water and *incondensible* steam were not disposed of, and how to rid the condenser of these was long a matter of difficulty. The water, indeed, could be allowed to run off, by having a pipe whose length would exceed that of a column of water equivalent to the pressure of the atmosphere, but the air was not removed. At

last it occurred to him that a pump would draw off both air and water, and preserve a perfect vacuum in the condenser.

Thus was completed one of the greatest inventions ever known. By the simple operation of thought, in a few days, was effected that which had hitherto been deemed an impossibility—*a hot cylinder and a perfect vacuum.*

We should act unfairly if we concealed that Mr. Watt has been denied, by some men of great respectability, the merit of discovering the separate condenser. Hornblower says, "It occurred to Mr. Gainsborough, the pastor of a dissenting congregation at Henley on Thames, and brother to the painter of that name, that it would be a great improvement to condense the steam in a vessel distinct from the cylinder where the vacuum was formed; and he undertook a set of experiments to apply the principle he had established, which he did, by placing a small vessel by the side of the cylinder, which was to receive just so much steam from the boiler as would discharge the air and condensing water, in the same manner as was the practice from the cylinder itself in the Newcomenian method, that is, by the shifting valve and sinking pipe. In this manner he used no more steam than was just necessary for that particular purpose. The circumstances as here related receive some confirmation by a declaration of Mr. Gainsborough, the painter, to Mr. J. More, late secretary to the Society of Arts, who gave the writer of this article the information. Whether he clothed the cylinder as Mr. Watt does, is uncertain; but his model succeeded so well, as to induce some of the Cornish adventurers to send their engineers to examine it; and their report was so favourable as to induce an intention of adopting it. This, however, was soon after Mr. Watt had his Act of Parliament passed for the extension of his term; and he had at the same time made proposals to the Cornish gentlemen to send his engine into that county. This necessarily brought on a competition, in which Mr. Watt succeeded; but it was asserted by Mr. Gainsborough, that the mode of condensing out of the cylinder was communicated to Mr. Watt by the officious folly of an acquaintance, who was fully informed of what Mr. Gainsborough had in hand."

At this date it is impossible to decide the merits of their respective claims. It does not appear that much credence has been given to the statement of Hornblower by recent writers, but we certainly consider that it throws considerable doubt upon the matter. We by no means think with Dr. Brewster, that Hornblower's ignorance of these circumstances, when examined before the House of Commons, precluded the possibility of his knowing them afterwards. But there is so much detraction where there is merit, that we sincerely hope this solitary testimony is dubious, especially when we consider that Mr. Hornblower was a rival of Watt during the whole of his career.

The accompanying drawing represents Watt's engine, with nearly all his improvements, and exhibits it in a state of perfection to which it was only brought at a late period of his life. It serves our purpose better to explain his successive alterations and additions in this way, than to give separate and unconnected diagrams, which would but convey to our readers an obscure and indefinite idea of their arrangement. We shall first proceed to explain the principle of this machine, and afterwards detail the dates of the improvements as they were added.

Our readers must suppose the cylinder, *a*, to resemble that of Newcomen's engine, excepting that it is more accurately bored, so that it may be perfectly cylindrical throughout.* It is fitted with a lid or covering at top and bottom, instead of being left open at top as in the old engine. In the centre of the upper covering is a hole, through which the piston rod passes; on this lid is the stuffing box *c*, the lower part of which consists of a hoop

* This required a degree of perfection in the art of boring, which had not been attained previously to the time of Watt. The method hitherto adopted had been to depend upon the accuracy of the casting for the guidance of the cutter, and as this was either frequently untrue, or in some parts softer than in others, the boring varied from the true cylindrical form, when either of these mischances arose. The improved method obviated these objections by fixing the cutter block firmly upon a cylindrical bar, and causing the cylinder to revolve after it had been accurately chucked, and the cutter block was propelled the length of the cylinder by a screw in the interior of the bar.

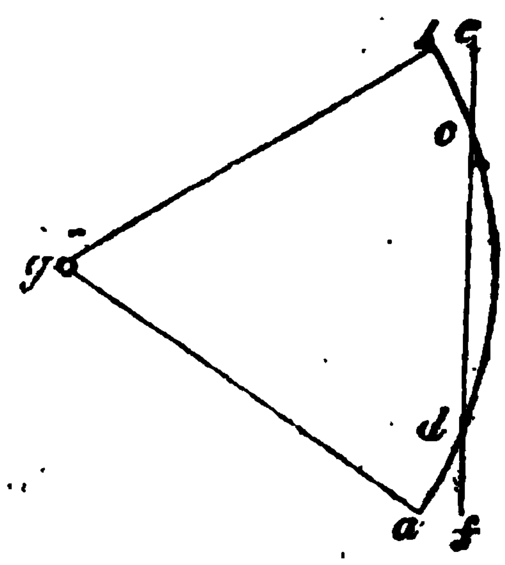
(Watt's Engine.)

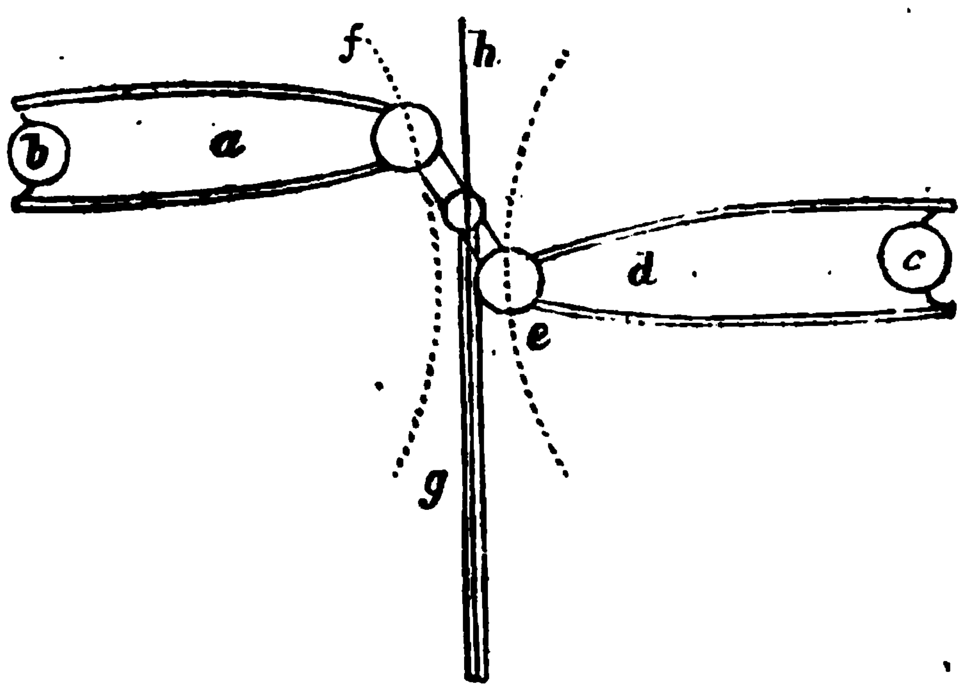
or cavity, with a flanch and screw holes. The interioı of the cavity is large enough to admit some soft vegetable substance (hemp or cotton) to surround the piston rod, which is likewise accurately turned. The covering, or upper part of the stuffing box, is less than the interior of the cavity in which the stuffing is lodged; when, therefore, the screws are tightened, the upper part presses the stuffing closely to the piston rod, and prevents the escape of steam. *d* is the beam made of cast iron; it rests upon the centre, *e*, and is connected at the farther end by the connecting rod, *f*, to the fly wheel, *g*, the axis of which drives the machinery. The mode by which the revolution of the fly wheel is effected, is by what is called a *sun* and *planet motion*, and may be thus explained:—*h* is a toothed wheel, bolted on to the connecting rod, so that it cannot revolve upon its axis. *o* is likewise a toothed wheel, fixed to the fly wheel axis, so that they cannot revolve but in conjunction. The centres of the two wheels are connected by a bar, so that the centre of the wheel *h* describes a circle, of which the fly wheel axis is the centre. The fly wheel, in this instance, makes a revolution at each stroke of the piston, differing essentially from the common crank, which makes but one revolution for two strokes of the piston. The latter may be compared to a man turning an axle by a handle, whilst the former is like the same axle turned by a wheel, *fixed* upon the handle. The principle will be better understood by reference to our drawing.

Let us suppose the connecting rod to be descending. At present, the points *o o* are in contact; but, when the connecting rod has descended to the lowest part of its circle, the points *q q* will be in contact; the number of teeth between *o* and *q* corresponding in each wheel; but this cannot take place until the wheel *h* be directly under the wheel on the fly wheel axis; and as the piston has but half a stroke to make before the wheel *h* will be under the other wheel, the latter wheel must perform a semi-revolution, whilst the centre *h* has only described one-fourth, or, in other words, for each half stroke of the piston: and a whole revolution for each stroke thereof. The advantages

of which are, that the fly wheel makes twice the number of revolutions by this method, than it would by the common crank, so that a lighter fly wheel is required; besides which, it is extremely convenient where a rapid motion is necessary. There are, however, several disadvantages attending it, among which may be enumerated those of its being less simple, more expensive, and more easily deranged.

h e m is the parallel motion; the purpose of this is, to keep the piston rod perpendicular, whilst the end of the beam (to which it is attached) describes a segment of a circle. *e f* represents the motion of the piston rod, and *b c d a* the motion of the end of the beam, the centre of which is at *g*. The points *c d* are the only parts where the two motions coincide; and it would be impracticable to connect a piston rod, the movement of which is rectilineal, with the end of a beam whose movement is curvilineal, except by a rack and sector. This was tried, and found extremely objectionable, and finally gave way to the parallel motion.





The following explanation will inform our readers of the principle of all such parallel motions. *a* represents a beam, of which *b* is the centre, and *c d* another beam of

equal length. *ef* is a rod joined to the end *e* of the beam *d*, and the end of the beam *f* of the beam *a*. The piston rod *g* is attached to the middle of the piece *ef*; and as the beams are of equal radii, therefore the versed sizes are equal, but in opposite directions, so that they correct each other; for when the end *f* of *e f* is at any given distance from the perpendicular line *g h*, the lower point *e* of *e f* is drawn the same distance from the perpendicular in the contrary direction; and thus the centre of the piece *e f* will always remain in the parallel line *g h*.

Though we may thus illustrate the principle of the parallel motion, yet this method is seldom or never adopted, as it requires much extra room; because the beam *c d* being half the length of the main beam, the engine house must, to admit it, be nearly one half longer than is required for the beam alone. The form generally preferred is that given in our connected drawing, to which we will refer. The piston rod is attached by pivots to the end of the rod or rods *r*, which are also connected by pivots to the end of the beam. The rods *g m* are of equal length with those attached to the piston, and turn upon similar pivots on the beam. These rods are connected by the bridle *k*, so that the ends of *m* and *r* describe a similar line when in motion. The beam or rod *e m* is equal in length to the part of the beam *e g*, so that *e g m e* would separately exhibit the same appearance, and produce the same effect as would the apparatus exhibited in our last diagram: that is to say, there is a point in *g m* which describes a rectilineal motion. We have already shown, that, by the rod *k*, the pieces *g m* and the pieces *r* must act in conjunction; so that if a parallel motion be obtained in *g m*, it must likewise be obtained in *r*. To that part of *r* the piston rod is attached, and is thereby kept parallel during the ascent and descent of the beam.

The governor or pendulum, *s*, is used for regulating the quantity of steam admitted into the cylinder, and may be easily understood. The balls are heavy, and rise or fall according to the speed. When the engine goes too

quickly, they also revolve with equal rapidity; the centrifugal force of the balls being thus increased, they recede from the centre, and thereby raise the levers by which they are suspended; these levers are connected with the shorter ones *u u*, which, in expanding, cause the ring or strap, *w*, to descend. Into a groove of this ring a fork or semicircle is made to fit, which is fixed to the end of the lever *w* H; so that as much as the strap ascends, the farther end of the lever descends, and by the rod, H Z, depresses the handle of the throttle valve, Z, which is a vane in the interior of the steam pipe, of such dimensions as to completely fill the pipe in one position, and by presenting its edge to the steam in another, to oppose no resistance to the entrance of the steam.

We must now return to the cylinder and condenser, the latter of which is not shewn, but may be briefly described. It consists of a tube immersed in cold water, and connected at the bottom by a pipe to a pump, which is worked by the rod, 4. The use of this pump is to preserve the vacuum by drawing off uncondensed vapour and the water of injection. It acts precisely on the same principle as the common air pump, and bears the same name, the receiver of the air pump being the condenser of the engine, and the pump similar in both. We will now suppose steam admitted from the cylinder: a valve, called the *blowing valve*, is opened, which permits the steam to enter the cylinder and condenser, and drive out the air. When the air is expelled, which may be known by the crackling noise and ebullition which takes place in the water, (the former arising from the globules of pure steam rapidly condensing, and the water thereby collapsing,) the blowing valve is shut, and the valves arranged so that the steam can enter the upper part of the cylinder. The steam acting in conjunction with the vacuum now formed on the lower side of the piston causes it to descend to the bottom. The lever, 1, is now turned downwards, and shuts that valve, whilst 2, on a pipe behind that which we see, opens a passage to the condenser. The lever, 3, is at the same time

opened, admitting the steam under the piston, which consequently ascends. In the act of rising, a jet of cold water is admitted into the condenser, which expedites the condensation. There are a number of tappets on the pump rod, 4, which repeat the changing of the valves when the engine is left to itself. The water in the reservoir surrounding the condenser would be soon heated by the steam, but that a pump worked by the rod, 5, keeps a constant supply of cold water from the well. 6 is a small pump, which supplies the boiler with water from the heated water drawn out of the condenser.

Having now explained the mode of operation, we have to state that the first engines were used for pumping water, and for that purpose alone. The first engine, therefore, was, like Newcomen's, a single acting one, as its power was only exerted in one direction. It was covered at the top like the double engine, but, instead of having the steam and vacuum to aid it in both ascent and descent, the vacuum was only used in the descending stroke of the piston, whilst the ascending one was effected by a heavy weight or counterpoise at the further end of the beam. During the latter operation, the steam was admitted by a valve from the *upper* to the *under* side of the piston, and was there used for forming the vacuum below. By this method the air was entirely excluded from the cylinder.

The first engine was of this description; it was erected on the estate of the Duke of Hamilton, at Kenneil, about a mile from Borrowstoness, in Scotland. The cylinder was eighteen inches in diameter, "and it was successively altered and improved, until it was brought to considerable perfection." In 1768 and 9, a patent was procured, in conjunction with Dr. Roebuck, (the founder of the Carron Iron Works, and through whose interests the experimental engine had been erected at Kenneil,) and arrangements were made to manufacture on a large scale, when, from pecuniary embarrassments, the Doctor was obliged to withdraw his promised aid, and Watt was about to abandon his project. It forturately happened, however, that

a negotiation was opened with Mr. Matthew Bolton, of Birmingham, which was concluded in 1773.

From this time things went on successfully; his colleague was a man of wealth and influence, and lent his utmost aid to the extension of the sale, which was effected with great difficulty, chiefly arising from the increased cost of erection. The patentees erected the engines at such prices as could be obtained, and received a third part of the saving of coal, which saving was decided by a machine somewhat similar to that which was used on Waterloo, Southwark, and Vauxhall bridges. It consisted of a train of wheel-work, working like clock-work, commonly attached to the beam in such a manner that by every stroke of the engine it moved one tooth, so that the index told how many strokes had been made since last examined Two sets of keys were kept, one by the proprietors, and the other by the traveller of Messrs. Bolton and Watt, who went round at stated periods, and ascertained the number of strokes which the engine had made during his absence, and the consumption of coal, in proportion to the work done, having been previously decided, the advantage of their engine over the atmospheric was easily known.

In the early engines a rack and sector were used for the purpose of working the beam by the piston; but this was very defective, and easily disarranged, especially when the direction was reversed. This gave way to the parallel motion, one of the brightest thoughts which ever occurred to Mr. Watt.

Another difficulty was the irregular motion of the engine, which was subject to considerable variation in speed, as the supply of steam in the boiler varied. This was obviated by the governor acting upon the throttle valve, which, we have already shown, admitted more or less steam, as the speed decreased or increased. The governor was not Watt's invention, but had been previously used in corn mills, which were subject to similar irregularity. When the stones moved too quickly, the meal, by the rise of the stones, was too coarse; when, on the contrary, the motion was slow, the meal produced was

small in quantity, and too fine. The governor, or as it was then called the *tent-lifter*, brought the mill-stones nearer when in rapid motion, and removed them farther off when slow. This ingenious regulator was applied by Mr. Watt to his throttle valve, and has been ever since used for that purpose.

Mr. Watt, in 1778, states, that he contemplated the practicability of obtaining a rotative motion from the reciprocating one; and for this purpose he thought of the crank, (for which we have seen that Hulls had previously obtained a patent, but which was unknown to Mr. Watt), and when he had nearly brought his project to bear, and was about taking out a patent for it, he found that a Mr. Wasbrough, of Bristol, had already obtained a patent for the crank; Mr. Watt, therefore, finding himself thus prevented from using his invention, set about something which might answer the purpose instead. This he effected by his sun and planet wheel, which possesses, as we have said, some advantages over the other.

An important improvement of Mr. Watt's was carried into practice in 1778. It consists in shutting off the steam from the cylinder, some time before the piston has completed its stroke, so that the remainder may be performed by the expansion of the steam already contained in the cylinder. This serves as a method of regulating the acting force of the engine, because, as the steam can be shut off at any part of the ascending or descending stroke, so much steam may be admitted as barely to carry the piston through its required motion, and, by the adjustment of the valve gear, the quantity of steam admitted may at all times be varied in an instant. If this were the only advantage, it is a great one; but we shall make it apparent that a great saving of fuel will likewise be effected by this method.

If the whole stroke of the piston be divided into a given number of parts, say ten, and each subdivided, the pressure will vary in each subdivision, according to the following table. The pressure of steam is assumed to be equal

to fourteen pounds on the inch, and the length of the stroke to be eight feet.

	Portions of the descent from the top of the cylinder.		Proportion of the pressure of the steam on the piston to the whole pressure of 14 lbs. per square inch.	
	·05	....	1·	
	·1	Full supply of	1·	This is the full pressure of
	·15	steam from the	1·	14℔ per inch, before the supply
	·2	boiler........	1·	of steam is shut off.
One fourth, or	·25	....	1·	
	·3	....	0·83	
	·35	....	0·714	
	·4	....	0·625	
	·45	....	0·555	
One half, or	·5	....	0.5	—½ the original pressure, or 7½ ℔ ⅌ sq. inch
	·55	Supply of	0·454	
	·6	steam cut off,	0·417	
	·65	and the descent	0·385	
	·7	is produced by	0·375	
Three fourths, or	·75	expansion only	0·333	—⅓ the original pressure, or 4⅔℔
	·8	....	0·312	
	·85	....	0·294	
	·9	....	0·277	
	·95	....	0·262	
Bottom of the Cylinder.	1.	....	0·25	—¼ the original pressure, or 3½℔
			11.583	

It is stated in the specification that the sum of all the varying powers is greater than fifty-seven hundredth parts of the original power multiplied by the length of the cylinder, whereby only one fourth of the steam necessary to fill the cylinder is employed, and the effect is more than half that which would have been produced by the cylinder full of steam. Thus the sum of all the numbers which express the action of the steam, taken at twenty different places in the descent, is 11·583; whilst the whole pressure, represented by 1, and taken likewise at different places, will be 20; it is, therefore, $\frac{11.583}{20}$, or $\frac{57}{100}$.

This is a curious fact, and sufficiently proves the great economy of the expansive principle. For, had steam been admitted during the whole of the stroke, the accumulated pressure would have been 6333×4, or 25,332 lbs. The quantity of steam consumed during this stroke would have been four times more than if it had been shut off at one fourth of the stroke, and yet the effect of the whole is only

five thirds of that produced by the latter. One fourth of the steam performs three fifths of the work which would have been performed by the whole.

The boiler of Mr. Watt's engines was generally made of what is called the waggon form, and so placed on the furnace that the flame passes through a long flue, which goes twice round the bottom part of the boiler. In order to ascertain the height of the water in the boiler, two guage cocks are employed, one a little above, and the other a little below the proper level of the water. Consequently, if the water be at the proper height, the lower cock will emit water, and the higher one, steam. If water should issue from both, it is evident that there is too much in the boiler; but if steam only be given out, then it is too low. The supply of water is kept up by a small pump, shewn at 6, in our drawing, which is fed from the hot-well.

The apparatus on which the safety of all steam engines depends, is the safety valve; that of Mr. Watt was of the lever kind; the valve itself is conical, and so loaded that its weight may exceed the force of the steam within. As soon as the pressure exceeds the load on the valve, it lifts it up, and the steam blows off until the equilibrium be restored. There is likewise another safety valve, which opens inwards, being balanced likewise by a lever and weight, to keep it shut. Its use is to prevent the sides of the boiler from being crushed by the pressure of the atmosphere, when the engine has stopped, and the steam within is condensed by the removal of the fire.

We now come to speak of the imperfections attendant on the Bolton and Watt engine: these are, friction from the rubbing of the moving parts against each other—the reciprocation of the machinery, and the irregularity of the motion: we shall notice them successively.

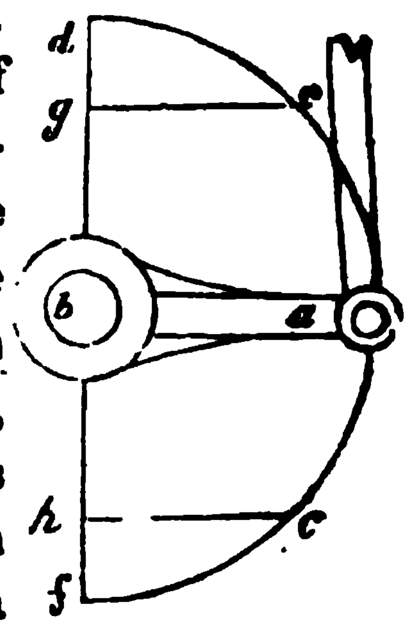
First, The rubbing of the parts against each other.—This evil must exist in every conceivable form into which

the steam engine may be modified, but no doubt the quantity may be considerubly reduced. The steam, in order that its full effect may be obtained, acts against a moveable piston in a cylinder from which it cannot escape. This piston is, as has been explained, packed or stuffed on its edges, which prevents the steam from escaping past it; and from the nature of the material used for packing, and the tightness with which it is pressed against the cylinder, the friction arises. This is sometimes so great, that we have seen engines where the whole force of the steam could not give them motion. It is usually estimated at one third of the power of the steam—that is to say, if the steam acted upon a piston with a force of 1500 lbs., the effect produced would not exceed 1000 lbs., a power of 500 lbs. having been absorbed by the movement of the machinery alone.

The next objection is the reciprocation of the parts. This is an evil of considerable magnitude. It originates from an inherent law in matter, by which all bodies have a tendency to continue in the motion communicated to them, or remain in their natural state of rest. If a ball be discharged from the mouth of a cannon, it requires an exertion of force to give it an impetus greater than would be required to continue its motion. If its progress be arrested whilst in motion, a shock will be experienced by the body which impedes it, the force of which shock will vary as the velocity of the ball. When this ball ceases to move without any *visible* impediment, it is not that its original impetus is exhausted or spent, (though the latter term is frequently used,) but that it is gradually overcome by the particles of air, which form a succession of points of resistance, and the attraction of gravitation, which has a tendency to draw it towards the centre of the earth. Were it not for the operation of these combined but invisible forces, the ball would continue in motion for ever, because nothing would intervene to destroy the primary impetus. This property of matter occasions a considerable destruction of power in the steam

engine. The motion of a massive beam, and its necessary appendages of machinery, a piston, connecting rod, parallel motion, and pump buckets, have to be reversed at each stroke of the engine, and that, too, when the speed is very great. The natural state of rest, or *vis inertiæ*, (*i. e.* the force of inactivity,) has to be overcome at the commencement of each stroke; and when a great velocity is acquired, it is as suddenly checked to prepare for the returning one. This unavoidably produces a great strain upon the machinery, which must be made proportionably more massive: and it requires likewise great skill in the construction of the engine house, to prevent its being ultimately destroyed, by the alternate push and pull which it experiences at each reversion of the beam. We have frequently seen the best constructed engine houses shaken, and almost falling to pieces from this cause.

Various schemes have been proposed, to remedy one of the evils of reciprocation. We mean the shock experienced by the reversion of the motion. It is not expected to prevent the loss of power sustained thereby; for that must remain as long as the law of which we have just spoken exists. Where a crank and fly wheel are used to obtain a rotatory motion, a *shock* is prevented by the velocity being gradually retarded, the crank having to perform a greater portion of its revolution with only the same surface of steam at the commencement and termination of each stroke of the piston: we explain our meaning by reference to the marginal diagram. *a b* is the crank of a steam engine, of which the semi-circle *d, c, a, c, f*, represents the motion communicated by one stroke of the piston; when, therefore, the crank in its present position is moved from *a* to *c*, the piston is at its greatest speed, and travels nearly at the same velocity as the point *a* of the crank. But when moving from *c* to *d*, an equal portion of a revolution, the piston only moves a distance equal to *g d*,



in the same space of time, as it had previously moved a distance equal to $b\ g$, almost double of $d\ g$. Hence it appears that the crank, by gradually decreasing the speed, is admirably adapted for preventing the violent shock which would otherwise be experienced by the piston striking the top and bottom of the cylinder, and by changing the motion of the beam too suddenly; but it does nothing towards reducing the power lost by reciprocation. In pumping engines, where a fly wheel and crank are not used, other means are adopted to check the force of the piston, or guard against the shock of suddenly changing the motion of the beam. In the coal districts, the usual way is to shut off the steam when a part of the stroke has been performed; the expansive force of that already in the cylinder, together with the impetus of the piston sufficing to barely carry it to the termination without violence. In such engines, springs are sometimes fixed above and below the beam, so as to check its progress, should the steam possess more force than may be expected. "It once happened," says Mr. Farey, "that the valve of the pump bucket breaking, the engine suddenly lost its load or resistance, which occasioned the piston to descend and strike on the spring beams for two or three successive strokes with such violence as to break one of the beams, and at last the piston striking the bottom of the cylinder, the *momentum of the beam* forced down upon the rod so violently as to bend the great piston rod quite crooked. To prevent similar accidents, a smaller steam pipe was added to the side of the vertical steam pipe communicating with the passage into the bottom of the cylinder. This pipe is kept closed by a valve; but if the engine descends so low as to strike on the spring beam, a catch pin on the beam strikes a small lever, and by a wire of communication opens the valve, and lets the steam into the lower part of the cylinder beneath the piston and thus destroys the vacuum, so as to prevent the farther descent of the piston."

This addition, it will be understood, applied only to the

single acting engine, but it serves to show that the objections which we have given arising from momentum are not merely theoretical.

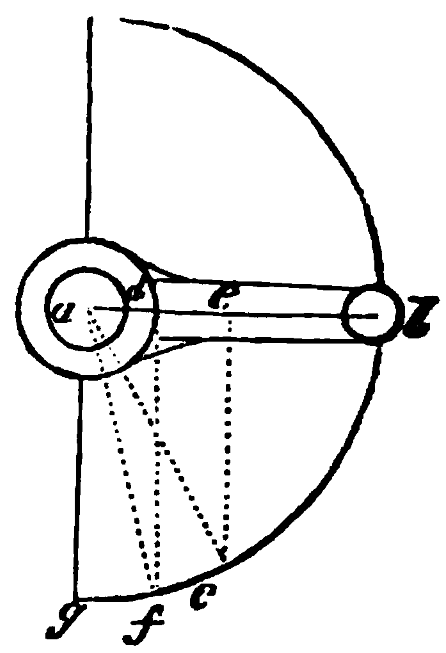
The beautiful addition of the crank to the steam engine, although the means of extending its utility tenfold, has been the subject of much objection. Engineers and others possessing considerable claims to the character of scientific men, have not unfrequently maintained that there is a considerable loss of power by the change in the length of the lever as the crank revolves. We shall endeavour to show the error into which such persons have fallen

The principle of the lever is so well known, that it is scarcely necessary to explain it: lest, however, it should not present itself to all our readers, we will give a short description. "In all levers, the universal property is, that the effect of either the weight or the power, to turn the lever about the fulcrum, is directly as its intensity and its distance from the prop; whence it is deduced, that if parallel forces acting perpendicularly upon a straight lever keep it in equilibrio, they will be to each other reciprocally, as the distances from the fulcrum upon which they act."* Thus, supposing a bar of four feet in length be fixed upon a fulcrum exactly in the middle, and an ounce weight be suspended at each end, the two ends will be in equilibrio, because the force of gravitation is equal, neither possessing it in a greater degree; but if the fulcrum be shifted and placed three feet from one end, then it will require three ounces at the shorter end, to balance one ounce at the other. If motion be given to the shorter end whilst the fulcrum remains the same, the end of the longer lever will traverse three times the space of the shorter.

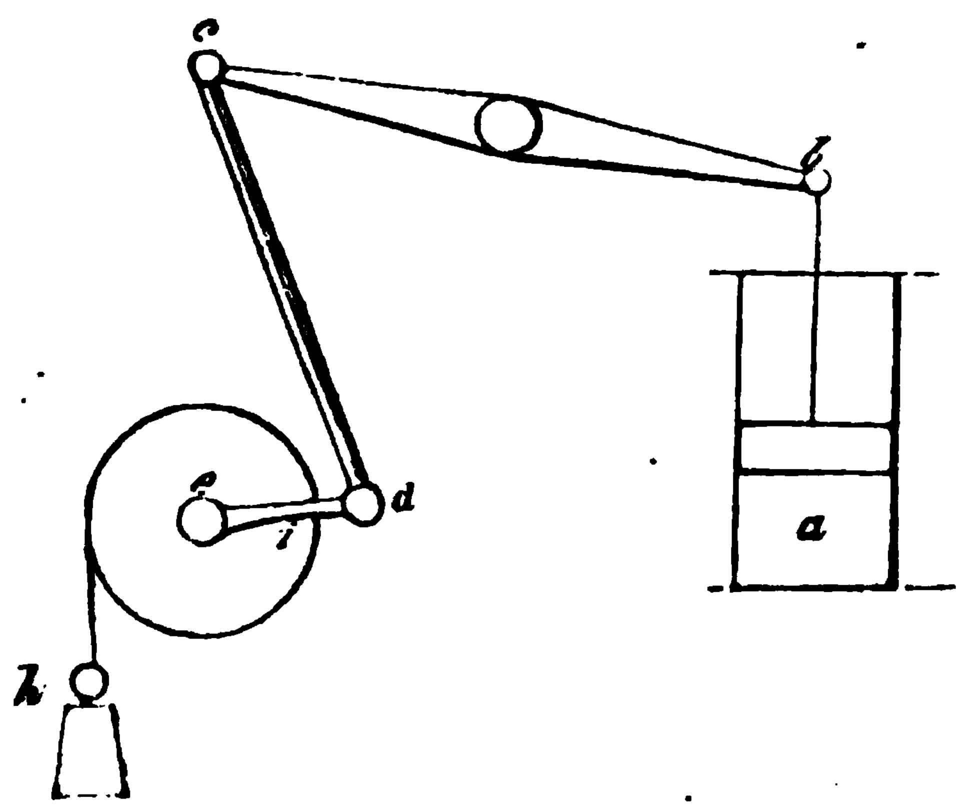
The crank of a steam engine is a lever whose fulcrum is at *a*. It is the nature of the crank that its power or leverage varies with its position. Let *a b* represent the crank, the point *b* is moved by the connecting rod, and revolves round the centre *a*. Supposing the resistance be

* Good and Gregory.

equal to 100 lbs., or that 100 lbs. have to be raised 3.1416 feet for every revolution of the crank—it is evident if a force or weight exceeding 100 lbs. be applied at *b*, whilst the crank is horizontal, it will be sufficient to raise the weight. But when the point *b* has descended to *c*, the length of the lever being described by its sine, the vertical line *e c*, drawn through *a b*, shows *e a* to be the length of the lever, which is only one half of *b a*. It would, therefore, require a weight double of the former to continue the motion. And if the crank descend to *f*, the vertical line, *d f*, shows *d a* to be the length of the lever, and to be only one fourth of what it was when horizontal. When it reaches *g*, no power on earth applied through the medium of the connecting rod, would continue the motion further.

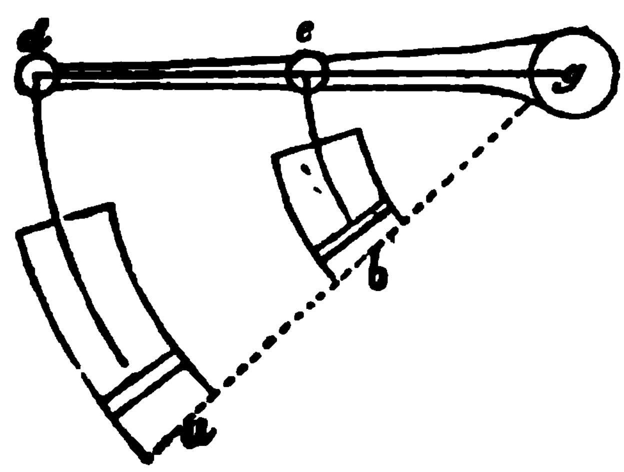


To equalise this irregularity, and in some degree to compensate for this great variation, the cylinder is of such dimensions as to give out a considerably greater power when the crank is horizontal than is then necessary. This extra power is employed to give motion to the fly wheel, which is of sufficient dimensions to retain the impetus until it be past the point *d*, when the steam begins to act with effect upon the lower side of the piston.



Let *a* represent a cylinder, the length of the stroke of the piston being two feet. *d e* is the crank, the length of which is one foot; *b c*, the beam, the fulcrum of which is exactly in the middle. If the piston be put in motion, the extreme end of the crank will describe a semi-circle of 3.1416 feet. Now, let us suppose that a drum be fixed upon the axle *e*, whose circumference is four feet, equal to one ascending and one descending stroke of the piston If a weight be suspended by a rope to this drum, as at *h*, the power of the engine at that point will exceed the power necessary to raise the weight as much as *d e* exceeds *i e*. This extra power is communicated to the fly wheel, which faithfully gives it out when required. When the crank has descended so as to decrease the length of the lever, that it is shorter than *i e*, then a portion of the extra power in the fly wheel is absorbed in aiding the decreased leverage of the crank. And although the power gradually decreases, yet the speed of the piston gradually decreases also; so that if the power of the crank be only one half in a certain position, yet the quantity of steam used is only one half, and thus the effect of no part of the steam is wasted, the effect being in every point equal to the steam expended. It is true, that if we could have applied the power at a point equidistant from the centre in every part of the revolution, we should have obtained much greater leverage, but then the expenditure of the steam would have been proportionably greater.

We will further explain this theory by referring to another diagram. *g d* represents a lever like the crank: *g* being the axle. *a b* are two vessels fitted with pistons, and in every respect resembling cylinders, excepting that they are curved so as to describe portions of circles formed from the point *g*. We will suppose that the piston



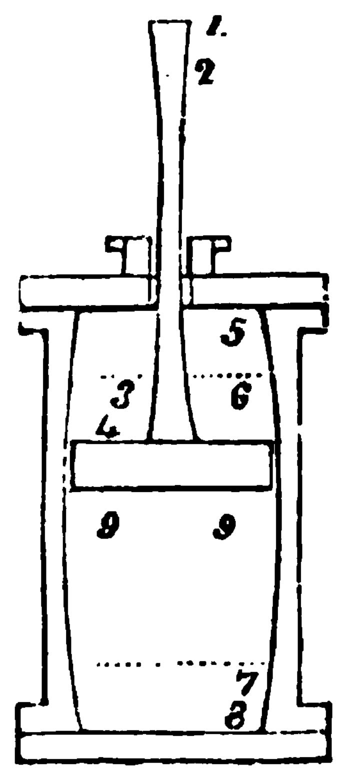
in *a* acts upon the extremity of the crank, and that in *b* at

half the distance from the centre. The vessels are of the same area, so that if steam were introduced from a boiler, it would press with equal force upon each piston, and consequently the rods would each press with an equal force upon the points, *e d*. Now it would be maintained, that, because at *e* there is only half the leverage, therefore half the effect of the steam in *b* is lost; but it will be found, that if that lever, *g d*, be moved any given distance round its centre, that the piston, *b*, only moves half the distance of the piston, *a*; and, consequently, the areas being equal, and the distance but one half, only half the steam is expended. Hence it is clear, that the consumption of the steam in every point of the lever is only equal to the effect produced.

There are minor objections against Watt's engine, which, nevertheless, should be noticed. One is, the waste of steam at the reversion of the motion of the piston. First, from the pipes between the valve and the cylinder. In filling the cylinder these must be filled, and in discharging, these must likewise be emptied; so that they are filled and emptied at each change of the motion. But in the cylinder every particle of the steam produces an effect; whilst here the steam used produces no effect, and is therefore wasted. Secondly, from the changing of the valves themselves at the improper time. Indeed, there is no time at which they can be changed without disadvantage by loss of steam; and the difficulty of determining the precise time frequently occasions their being changed at such a time as to waste more steam than is necessary. The unavoidable waste arises from the change of the valves being a work of time, whilst the reversion of the stroke is instantaneous: therefore, either the change of valves begins too soon, and admits steam into the vacuum before the stroke be completed, or ends too late, and admits steam into that part of the cylinder when a vacuum is forming, thereby preventing its formation, or otherwise it is attended with both these disadvantages.

Another disadvantage is the unequal form into which

the cylinder and piston rod become worn, after having been some years in use. This arises from the varied speed at which they travel, and to their not passing over all parts of the surface. We have seen in use, a piston rod and cylinder almost as much out of form as that in the drawing. The form of the piston rod arises from the parts 1, 2, and 3, 4, being only partially drawn through the stuffing box, consequently less *rubbed* than the middle, which is drawn through at each stroke. The decreased diameter in the middle of the rod arises from the speed being greater there than at other parts, (the cause of which we have already explained,) and creates in consequence a greater wear.

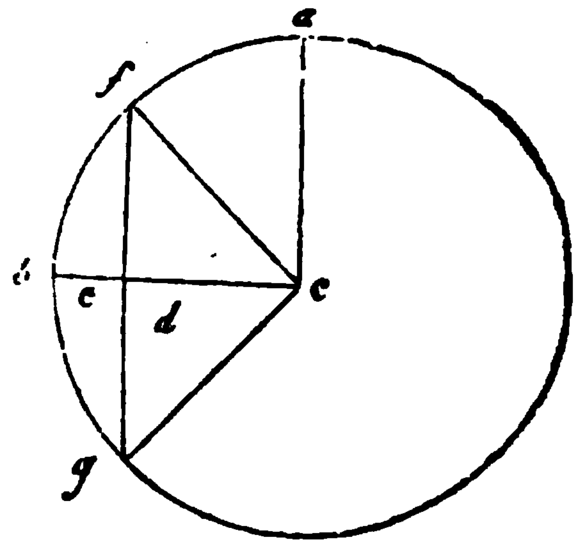


The irregular wear of the cylinder is produced in the same manner. The piston is not drawn through, but merely comes in contact, or is partially moved through 5, 6, and 7, 8, whilst it rapidly passes the middle, and therefore, in that part, it is more worn than at any other.

The last inconvenience we shall notice, though it is by no means the least, is, that the fly wheel is the constant and indispensable accompaniment of the crank. This will appear evident from what we have already stated.

Independently of extra cost, extra friction, and extra room, it becomes necessary to have two engines in steam boats, to obtain any thing like a regular motion, and even this is far from being regular. In steam boats, the two cranks are fixed upon the same axle as that on which the paddles are placed. By this contrivance, when the crank of one engine is passing the centre and has no power, the other is at its greatest power; and, thus aiding each other, something like an equality is preserved. But this is irregular, as a variation still takes place in the mean length of the wo levers.

a c, and *c b*, represent two cranks, the axle of which is *c*. *a c* is now passing the centre, and therefore has no



power; whilst the other, *c b*, is at its greatest power. The mean length of the lever, therefore, is at *d*, or one half of *c b*; but when the two cranks have made one eighth of a revolution, as to *c f*, and *c g*, then the line, *f g*, shows the mean power to be at *e*; having varied from *c d* to *c e*.—This irregularity being unaided by a fly wheel, may probably account for the vibration which we feel in many steam boats, and which appears to proceed from some other cause than the reciprocation of the parts. It should be observed that the impetus of the boat makes the paddles act as a kind of fly wheel; because, if they were suddenly disengaged from the machinery, they would continue to revolve of themselves, so long as the velocity of the stream was less than the velocity of the boat, because then the stream acts like a current driving an undershot wheel. So long as the vanes continued to be driven against the water, so long would the motion of the wheels be continued in the same direction as that given by the machinery; therefore, we say, that they are fly wheels of a peculiar kind; but still, as the speed would immediately decrease as they were disengaged from the machinery, from the yielding nature of the medium through which they pass, so also would they vary in velocity, as the mean power of the crank increases or diminishes.

It will be readily conceived that these disadvantages must have exercised the talent of many ingenious men. All have agreed that the remedy might be found in a circular or rotatory motion, obtained from the steam itself, without the aid of the beam, crank, or piston rod. If this could be effectually done, it would do away with almost every defect of which we have spoken. Reciprocation would be removed, as well as irregularity in the power of the lever; and, as for friction, that of the beam and appendages would, at all events, be destroyed: but it has been found that, hitherto, notwithstanding the advantages

attendant on this kind of engine, inconveniences and difficulties have been found, peculiar to each varied form, or common to all, that have precluded its adoption in preference to the reciprocating engine. The defect in many of them has been excessive friction, and, in nearly all, the difficulty of maintaining the packing steam tight: this is as much as we can say as to the general objection. We shall direct the attention of the reader to several of the best rotatory engines, and endeavour separately to shew the causes of failure.

The shrewd and investigating mind of Mr. Watt seems to have directed itself, in the very outset of his career, to the desirableness of such an engine: for we find, in his patent of 1769, (the specification of which we have examined,) that a rotative engine is one of the inventions included therein, and seems to claim precedence in his judgment (if we may judge by the order in which they stand) to the use of hemp and oil in packing, instead of water as in the old engines. We will extract that part of the specification verbatim :—

"Where motions round an axis are required, I make the steam vessels in form of hollow rings, or circular channels, with proper inlets and outlets for the steam, mounted on horizontal axles like the wheels of a water mill. Within them are placed a number of valves, that suffer any body to go round the channel in one direction only: in these steam vessels are placed weights, so fitted to them, as entirely to fill up a part or portion of their channels, yet rendered capable of moving freely in them, by the means hereinafter mentioned or specified. When the steam is admitted in these engines, between these weights and the valves, it acts equally on both, so as to raise the weight to one side of the wheel, and by the re-action on the valves successively, to give a circular motion to the wheel, the valves opening in the direction in which the weights are pressed, but not on the contrary. As the steam vessel moves round, it is supplied with steam from the boiler, and that which has performed its office may either be discharged by means of condensers, or into the open air."

There is a great deal of confusion and ambiguity in this part of the specification, as, indeed, there is throughout the whole; so much so, that we are surprised that the patent was ever sustained, since it is required that all specifications should be so clear, "that a person of moderate capacity, having a little knowledge of the science which led to the invention, can immediately see the method pointed out, and easily apprehend the purport for which the subject was invented, *without study*, without any invention of his own, and without experiments."* No drawings are given of any one of the six inventions included in this patent, and the reader may judge by this specimen whether any one can comprehend it without study. After much study we have been able to come at the meaning of the patentee, by supplying the form of the valves, and, indeed, most of the principal parts, and in that form we submit it to our readers as the *First Rotary Engine.*

(*Watt's First Rotary Engine.* 1769.)

* Godson on Patents, p. 109.

In explaining its principle, we shall repeat the words of the specification, making such alterations in the language as may make it understood.

"Where motions round an axis are required, I make the steam vessels in the form of hollow rings, or circular channels, with proper inlets and outlets for the steam," (as at *a* and *b*,) "mounted on horizontal axles," (*c*,) "like the wheels of a water mill. Within the *circular channel*" (*d d d*) "are placed a number of valves" (*e e e e*) "that suffer any body to go round the channel in one direction only: in *each steam vessel* is placed a weight," (*f*,) "so fitted to it," (by packing at *g*,) "as entirely to fill up a part or portion of its channel; yet rendered capable of moving freely in it by means hereinafter mentioned. When the steam is admitted between the *weight* and valves, it acts equally on both, so as to raise the weight to one side of the wheel; and by the re-action on the valves successively, to give a circular motion to the wheel, the valves opening in the direction in which the weights are pressed. As the steam vessel moves round, it is supplied with steam from the boiler, and that which has performed its office may either be discharged by means of condensers, or into the open air."

Now that we have made the language a little clearer, we shall proceed to describe such a machine as we imagine the inventor had in his mind; informing our readers that the hollow arms, form of the valves, manner of admitting the steam and allowing it to escape, are added as the best means we can devise to answer the proposed end; but we are not aware how they were really formed, nor whether at the time the specification was drawn up, the inventor had any decisive plans in view; or, that he (like too many patentees) trusted to the resources of his own mind to supply them when he proceeded on the experiment.

d d d is the circular channel, bolted together in segments, in which the weight, made of cast-iron or lead, *f*, can move freely. The weight is packed with hemp at *g*, so as at that part to fit so tight in the channel, as to prevent the steam from escaping past it. *i i i i* are four hollow arms, commu-

nicating with the hollow ring, and with a cylinder or bush *j j*, into which is fitted a circular plate of metal *k*, having two cavities *a b*, in the situation shown in the drawing. *k* is covered with another plate, to which it is accurately fitted; to this outer plate is attached the eduction pipe, which communicates with *a*, and the induction pipe which communicates with *b*; the plate *k*, and its covering, remain stationary, whilst the wheel revolves, and the open end of the arms *i i i i*, successively pass over the open spaces *a b*, and admit the steam, or suffer it to escape, as we shall now explain.

The steam being admitted from the boiler, rushes through the arm *i* 3, into the channel, and, shutting the valve *e* 1, or finding it already shut, forces up the weight *f f f* into one side of the wheel, (as shown in the drawing;) this causes that side to preponderate, and in endeavouring to regain its former position makes the wheel to revolve. But, in the mean time, a supply of steam is kept up from the boiler, which preserves the weight in its present position, driving the wheel round in the opposite direction, whilst the valve *e* 2, having passed the situation it is now in, is shut by the lever *l*, striking the tappet *m*, and receives the force of the steam, previously upon *e i*. When the wheel has revolved a little farther, the arm *i* 3 communicates with the eduction passage, and allows the steam to escape which was between the valves *e* 1 and *e* 2. Immediately after, the valve *e* 1 strikes against the friction roller *h*, and is by it forced into the recess, assuming the position of *e* 4. At the same time the valve *e* 3 has got clear from the weight, and falls, by its own gravity, into the position of *e* 2, after which it is shut by the tappet *m*, in the way already explained. Thus the valves successively receive the action of the steam, and the weight being preserved in its elevated position, the wheel continues to revolve.

Such was the plan designed as the first rotatory engine. It is because it *was* the first, and because it was the invention of Watt, that we place it here. In itself it possesses few claims to our attention. If such a machine could

ever be made, (which is doubtful,) the excessive friction of the weight moving in the channel would exceed that of the common engine tenfold. But the worst fault would be, that the packing could not be preserved steam tight for any length of time: for hempen packing, it is well known, cannot pass over in its course any cavity, or irregularity of surface, without been soon torn out, and rendered incapable of performing its office. It would also be required that the interior of the channel should be accurately turned, which might be effected in small engines by tuning a section of the wheel at once, (such as our drawing represents,) and afterwards bolting two of such sections together; but in large diameters, such as would be absolutely necessary for large powers, the vibration would render their being turned an absolute impossibility.

We cannot learn whether Watt ever proceeded on the experiment. He himself states that — "a steam wheel, moved by force of steam acting in a circular channel, against a valve on one side, and against a column of mercury, or other fluid metal, on the other side, was executed at Soho, upon a scale of six feet, and tried repeatedly, but was given up as several objections were found against it." From this we may conclude that the patented machine had probably been tried and abandoned, on the ground of excessive friction.

We have likewise some information on the subject of Mr. Watt's experiments on rotative engines, by Mr. Farey, (in his article "Steam Engine," which is to be found in Rees's Cyclopedia,) who says, "One of his first trials was uncommonly ingenious; it consisted of a drum turning air-tight within another, *with cavities so disposed* that there *was a constant and great pressure urging it in one direction;* but no packing of the common kind could preserve it air-tight with sufficient freedom of motion. He succeeded by immersing it in mercury, or in amalgam, which remained fluid at the heat of boiling water; but the continual action of the heat and steam, together with the friction, soon oxydated the fluid, and rendered it useless. He then

tried Parent or Barker's Mill, enclosing the arms in a metal drum, which was immersed in cold water. The steam rushed rapidly along the pipe which was the axis, and it was hoped that a great re-action would have been exerted at the end of the arms, but it was almost nothing. It was then tried in a drum kept boiling hot, but the impulse was very small in comparison with the expense of the steam."

The former part of this extract is about as obscure as the specification which we have just noticed. We should certainly have expected, from a man of Mr. Farey's experience, a somewhat clearer account of any experiment than that with which we are furnished; for, to say there "was a machine with cavities so disposed that there was a constant and great pressure urging it in one direction," conveys no further idea than that a motion was *somehow* obtained, but how, it is utterly impossible to know. The amount of this extract is, that Mr. Watt tried a great number of experiments, in order to obtain a rotatory engine, and that in these experiments he failed. The information we gather from Mr. Farey might have been said in as few words.

The second patent of 1782 (for there were two patents of that year, one in February and the other in July) describes a rotatory, and semi-rotatory, or reciprocating rotatory engine. To the rotatory engine we shall first direct the attention of the reader.

c c in the following figure is a cylinder of any given dimensions, say a foot deep, and three feet diameter. *a* is an axle, passing through stuffing boxes in each lid or end of the cylinder. *b* is the piston, packed at the ends, which rub against the cylinder, and at the sides which rub against the lids, which are previously turned; the form of this piston, therefore, is square, packed on three sides, and fixed to the axle *a* on the fourth. *e* is a valve or flap, which turns upon a joint or pivot *f*: the concave side is a segment of a circle of the same radius with the cylinder. It extends the whole length of the cylinder, is packed on its sides, and when shut back into the cavity *d*, becomes,

as it were, a part of the cylinder, completing the circle, which is imperfect when the valve is in its present situation. g is the pipe for admitting the steam from the boiler, and h the pipe for allowing it to escape into the condenser.

(*Watt's Second Rotary Engine.* 1782.)

Steam being admitted from the boiler through g presses equally upon e and b, but e being stopped against the axle, the piston b recedes from the pressure, and turns the axle a and a heavy fly wheel round with it. The piston continues in motion until it comes in contact with the lower side of the valve e, where it would stop, but for the impetus of the fly wheel, which urges it forward, and it strikes the valve e into the recess d, and moves round until it passes g, when the valve, either by a lever or by its own gravity, resumes its present situation, and the piston receives the action of the steam as before.

This plan, we are informed, was never carried into execution, and we must, therefore, as in other instances, endeavour to trace the objections from subsequent experience; but there have been so many schemes closely

resembling this, that these are easily ascertained. The principle objection appears to be that it would be liable to derangement, as the violence with which the valve would be alternately driven into the recess, and upon the axle, would speedily shake the machine to pieces; besides which, it would be impossible for the packing used in the reciprocating engine to pass over the pipes *h g*, without being torn up and rendered useless. A great waste of steam must likewise take place whilst the piston is passing over the surface of the valve: for at that time the steam pipe *g* has a free communication with the eduction pipe *h*; and every one acquainted with the subtle nature of steam must be aware that as much steam would thereby escape, without producing *any* effect, as would have been sufficient to work an engine free from that defect. This last objection might be obviated by shutting off the steam during that part of the revolution; but the specification proposes no such method, and we are not authorised to make any gratuitous addition.

The semi-rotative engine next comes under our notice. *d d* in the following figure exhibits the interior of the cylinder, which is similar to the last. It is likewise fitted with a piston *b*, packed in the same manner. *c* is a projection of metal extending from the circumference to the axle *a*. Packing is introduced between this projection and the axle, so as to prevent the steam from escaping between them. *e f* are two valves which admit steam from the steam pipe *g* into the cylinder on each side of *c* alternately. *o f* are two valves for changing the direction of the steam: *i j* are two valves acting in conjunction with *e f*, so as to open or shut off a communication with the condensers *l k*, through the pipe *h* at the proper time. Levers are attached to the rods by which these valves are worked, from tappets on the pump rods *r q*.

Steam is admitted from the boiler through the pipe *g* into the steam chest, and finding the valve *f* open, rushes up the pipe, and so into the cylinder between the piston and stop *c*. The piston, receding from the pressure, drives the air in the cylinder through the other pipe, and down

through the valve *j*, into the condenser, whence it escapes by the pump *l*. It continues revolving, until it comes in contact with the other side of *c*, when it is stopped; but, previously to this, the valves *f* and *j* have been shut by their respective levers, whilst *c* and *i* have been opened. The steam has now access through *e* to the other side of the piston, and turns it in the contrary direction; the steam which last performed its office escaping down through *i* to the condenser. The first operation is then repeated, reversing the motion of the piston as soon as, or before, it comes in contact with the other side of *e*. *n m* are two toothed wheels attached to the axle *a*, which work, (as shown) by racks, the pump rods *o p*, and the smaller pump rods *q r*. The former *o p* are supposed to draw water from a mine, but the smaller ones only work the condensing pumps *k l*.

(*Watt's Semi-rotative Engine.* 1782.)

This is really a clever machine. It was never, we understand, carried into execution, but why, we can scarcely tell. It would hardly be an objection that the

piston would strike against the stop *c*, and thereby shake itself to pieces: for here, as an equable motion is not required like a rotatory engine, the speed might (as in all pumping engines which were liable to the same objection) be gradually retarded, so that the impetus would be destroyed before it came in contact with the stop. Perhaps the most solid objection would be, that of the packing requiring more care than a common workman, such as generally attends to steam engines, would be able or willing to bestow; but if this were found a conquerable objection, we can scarcely conceive a reason why it should not have had a fair trial. It would have been extremely portable and cheap, would have occupied very little room, and the friction would have been comparatively trifling.

We now close our descriptions of Mr. Watt's inventions by giving a short account of a Rotatory Engine, included in his patent of 1784.

(FIG. 1.) (FIG. 2.)

(FIG. 3.)

(*Watt's Rotatory Engine.* 1784.)

Fig. 1. is a ground plan, and fig. 2. a vertical section. *a a* is an external cylinder, or reservoir, filled with heated water, quicksilver, or an amalgam which would become

fluid at the boiling point. *b b* is an interior cylinder in the middle of *a a*, and turning upon a pivot *o*. A partition, *c*, reaches from top to bottom, dividing the vessel into two equal parts. *d e* are two valves, allowing the liquid to ascend and fill the interior of *b b*, but preventing its egress in that direction. *f g* are two tubes, or apertures, for guiding the escape of the liquid in the direction of the arrow. *j* is the pipe for the admission, and *k* for the exit of the steam. The steam being introduced from the boiler through *j*, enters the cavity *l*, and passes on the surface of the water, driving open the valve *i*, (fig. 1.) and issuing through *g*, in the direction of the arrow, thus pressing upon the body of the liquid in the reservoir, and producing a re-action, which drives the internal vessel round. When it has performed nearly half a revolution, the cavity *n* comes under the steam passage. This will be understood better by fig. 3: *p p* is a hoop encircling the upper part, or neck, of the vessel *b b*; *l* is a hole in the side of the vessel communicating with one side of the vessel, and *n* a similar hole communicating with the other. It will be seen that, at present, the hole *l* communicates with *j*, and the hole *n* with *k*, but, by turning the vessel half-way round, their situations will be reversed; *l* communicating with *k*, and *j* with *n*, so that each side is successively exposed to the action of the steam and to the condenser. By this means, therefore, the hole *n* is next in communication with the steam pipe *j*, and the valve *d* being shut by the steam pressing on the surface of the liquid; the valve *i* is opened by the same means, so that the liquid is forced with violence through *f*, in the same manner as it was previously forced through *g*. Whilst this operation is going on, a vacuum is formed in the first vessel (by *l* communicating with the condenser), so that it becomes charged, and ready in its turn to receive the action of the steam. When it does, the first operation is repeated, and a rotatory motion is kept up by the alternate action of the liquid driving through the cavities *f g*, in nearly the same manner as the motion is produced in the well-known machine commonly called Barker's Mill,

differing only thus:—that the water from the latter acts against the air, whilst this acts upon the fluid in which this is immersed. The motion is carried through the top of the reservoir *a* to a stuffing box *q* (not shown), and attached to the machinery.

It appears this machine was tried, and found to have little or no power, which, of course, was the reason of its abandonment. The cause of its trifling effect arises from the force of the escaping liquid acting upon a medium which affords no solid resistance, and is therefore incapable of producing any powerful re-action in the machine.

We have always entertained an opinion that Mr. Watt's object in the drawing up of his specifications was to be as obscure as possible. In this opinion we are not solitary; as a proof of which, we make the following extracts from a letter addressed to Sir J. Eyre, then Lord Chief Justice of the Common Pleas, by Mr. J. Bramah, dated 1797.

Speaking of Mr. Watt's first specification, on which we have already remarked, Mr. Bramah says, "In considering the part arranged *first* in this specification, I cannot observe the words there used create in the mind of the reader any new idea respecting the construction, proportion, or office of that part of an engine properly called the steam cylinder. The inquirer is left wholly uninformed whether the intended cylinder, or steam vessel, is to be left open at top, and shut at bottom, or shut at top, and open at bottom, or whether both its ends are to be alike shut; nor is he directed in what manner the steam is to be admitted into the cylinder, or in what manner discharged: there being no mention how, and in what part of the cylinder, the necessary inlets and outlets are to be contrived, notwithstanding the essence of every engine depends thereon. There is likewise no mention made of the form and action of the piston, or the method of connecting it with the external and working parts of the machine, or whether the expansive force of the steam is exerted on the upper or under side of the said piston, or even whether there is a piston employed at all.

"This part of the specification appears calculated to

mislead and perplex; and I am fully persuaded, were these imperfect directions given to any workman, even of the most eminent knowledge in the art of building engines, they would tend directly to frustrate every regular step necessary to be taken in the progress of such a work.

"Had there been a shadow of a guide introduced into this mysterious composition, an ingenious mind might have accidentally stumbled on the inventor's mark; but it is so much the contrary, that every adventurer is constrained to explore a way for himself, and to wrap his cylinder in any warm covering his powers of judgment may suggest: and it is my firm opinion, that were engine builders in general left to puzzle out this single circumstance, ninety-nine out of every hundred would attempt a different method of accomplishing the inventor's intention; and I am likewise as fully convinced, that a like proportion would finally miss their aim, in spite of repeated efforts.

"The first thing which attracted my attention, when inspecting an engine built by Mr. Watt, was the steam cylinder, which I observed shut at both ends, contrary to that of Newcomen, which is always open at the upper end, whereby the atmosphere acts upon the upper surface of the piston, both in its ascent and descent.

"A slight pause on this circumstance soon presented to my view a total contradiction to the article in Mr. Watt's specification, denominated *fourthly*, where he asserts that 'He intends, in many cases, to employ the expansive force 'of steam to press on the pistons, or whatever may be used 'instead of them, *in the same manner as the pressure of the 'atmosphere is now employed in common fire-engines.*'

"On reading this paragraph, every person acquainted with Newcomen will naturally ask,—How can the expansive force of steam be applied to press down the piston in the manner it is now performed by the atmosphere, which requires the top of the cylinder to be kept open? For, suppose steam to be poured on to the top of it instead of air, where is there any footing or abutment for the re-action of this expansive element? I clearly perceive, says the inquirer, that the air performs this office by its gravitating

power, which requires no butment. But how can any expansive force be employed without it; since it is a law of nature that no force of this kind can be exerted without being first prevented from expanding on the contrary; or, at any rate, without having a resistance in all directions, equal at least to the force of action required?

"These reflections, I conceive, would induce a conclusion, that the man who proposed such a thing must be either a fool or a madman. But to return—

"On considering the strange difference I saw in this machine from that of Newcomen, I concluded in my own mind the following to be the real invention of Mr. Watt in the cylinder part of the engine. First,—He has completely inverted the order of Newcomen, by turning the cylinder upside down. Secondly,—By making the proper inlets and outlets for the steam, at the upper instead of the lower end of the cylinder. Thirdly,—The valves used in these inlets and outlets, for the purpose of admitting and shutting off the steam, and for retaining it in the cylinder and discharging it, the manner of giving motion to them from without, are very peculiarly and curiously contrived, and totally different from any article ever applied in Newcomen's Engines for the same purposes; and these valves, &c. I observe, are made always of brass, or a mixture of copper and brass; and I cannot see of what other metal such very essential parts could be made· as iron would soon rust, and in a few weeks lose the perfection requisite to keep them air and steam-tight. Fourthly,—I cast my eye on a single part of the engine, and which part not being properly accomplished, would render finally abortive all the efforts it is possible to make in giving motion and power to the machine.

"This, my lord, is the mean adopted for giving motion to the external mechanism of the engine, by connecting it with the piston, which is here close shut up in the internal part of the cylinder; and, as I have already observed, the cylinder is placed with its bottom upwards, compared with Newcomen's, this connexion between the internal and external motion must of necessity be communicated

through the bottom, which now becomes the top of the cylinder. As the entire effect of the engine depends on ascertaining a method of doing this completely, and seeming to form a most material part of the whole invention, I will be more particular in describing it to your lordship, and begin by stating how this was performed by Newcomen.

"In all Newcomen's engines, where the top of the cylinder was entirely open, the piston was connected with the working beam by a single or double iron chain; in most cases double at the upper end next the beam, and the lower end commonly formed a junction with the piston by an intermediate strong bar of iron, in some cases a strong rod of wood shod with iron. By this means, the force the piston received from the pressure of the atmosphere was communicated to the beam above, and that in as rough a manner as the workmen pleased to make it; the smoothness and truth of workmanship being unnecessary in this case.

"But, only behold, my lord, the difference required in Watt's engines in this one particular!

"The above two motions are to be connected by means of a rod or other contrivances, (for a chain, &c. will not answer here,) which must not only pass through an aperture in the cap or top of the cylinder, steam and air-tight, but this aperture is required to be kept thus close during every stroke the engine makes.

"This cannot fail of striking your lordship in a serious point of view; and, from what has been said, it must involve a conclusion in your mind, that this part is one grand essential, if not the most so, of any in the machine; as the smallest imperfection here will admit the air when the vacuum is made, and thereby completely stop the engine.

"Having thus prepared your lordship, I will now describe that which Mr. Watt should have done, *i.e.* the manner in which the internal piston is connected with the working beam without.

"This is by an iron rod of a sufficient diameter, turned

and otherwise worked so as to be perfectly smooth and parallel from one end to the other, and of a length sufficient to allow the full stroke of the piston within; and I think it necessary to remark, that if in this rod there should be the smallest rag or flaw, it is totally unfit for its purpose, for reasons that will appear hereafter. And I am certain, from my own knowledge, that Mr. Watt, in his first outset on this business, found more difficulty in procuring these rods in all respects perfect, than he would have done in constructing all the parts of Newcomen's engine; although this article, like the rest, is not mentioned in his specification.

"Fifthly,—I shall proceed to explain to your lordship a circumstance in this part of the engine, in my opinion, as material and of equal consequence with the preceding, or any other article in the machine. This is, the method of rendering the aperture, through which the piston rod passes, constantly air and steam-tight; notwithstanding the said rod, in many engines, slides through this aperture no less than three hundred and twenty feet per minute, during the time they work.

"This junction or aperture is a very ingenious contrivance, and is called a stuffing box; it is a part formed in the centre of the cap or top of the cylinder; and is a kind of cylindrical box, of about six or eight inches deep, made of iron. The upper part of this box is considerably wider than the diameter of the piston rod above-mentioned; and the bottom or lower part, next the inside of the cylinder, is made exactly to fit the said rod. From this part, for a small distance upwards, the box is turned in a conical form, so as to make a chamber exactly in the shape of a snuff mill; at the top of this conical part is turned rebate or seat, into which is fitted a brass or iron ring, the extreme circle of which exactly fits the cylindrical part above the conical part described. This conical chamber is then filled with hemp or junk, so as to surround the piston rod on all sides; and being secured down by the brass or iron ring above-mentioned, causes the rod to slide steam and air-tight. But the quantity of rub which is constantly

on this part, and the nice perfection required, soon discovered the want of some farther help; and something similar to the means just treated on for keeping the piston tight, suggested itself at an early period of Mr. Watt's experiments, which is effected as follows:—

"In the cylindrical part of the box is turned another rebate, about an inch more or less above the ring which secures the lower packing; and into this rebate is also fitted a ring as before, which causes a space between it and the lower ring. Then above the upper ring is turned another cylindrical part like the former, having, of necessity, a greater diameter. This conical chamber is likewise packed with hemp, junk, &c. and this packing also fastened down by means of a ring, rather more in a plug form, and so contrived as to admit of being screwed down at pleasure, for the purpose of compressing the packing as worn away by the friction of the rod. The stuffing box completed, a small tube is inserted by one of its ends at the side of the said box, so as to communicate with the open space comprehended between the rings. The contrary end of this tube is joined to the steam pipe or boiler, where the steam is always active; and by this means a constant supply of steam is thrown into the space aforesaid, which steam preserves the rod air-tight, being kept as strong or stronger than the pressure of the outward air. Thus the steam here does the office of water, &c. on the piston of the engine, when the packing becomes rather insufficient.

"I think, my lord, I need not say more on this point, to prove the necessity of a full and clear specification; and the practicability of giving one, had there been a willing mind.

"Sixthly,—I observe the lower end of the steam cylinder to be also closed, and that the steam has alternate communication with the cylinder above and below the piston, just contrary to that of Newcomen.

"To detail the true nature of all this, would be tiresome to your lordship; and, as Mr. Watt has not done it, I shall decline doing it for him, though certainly well able.

"Seventhly,—I come to what are called condensers. On this part of the subject I am almost puzzled what to say. From the specification, I can say nothing; from the engines, they have been made in all forms; and that, by changing about and mixing the knowledge of every person in his way for twenty years at least, Mr. Watt has been taught what is the real fact, and what they confessed to be so on the late trial, namely, that no condensers are necessary, but that, which Newcomen calls the eduction pipe, and in which the condensation is performed by a jet of cold water, answers the same purpose equally well.

"Then it appears, my lord, that twenty years' exercise of the superior abilities of Mr. Watt, with the help of all he could gain from the knowledge and practice of other men, and the assistance he received, through the space of six years more, from Professor Robinson, Dr. Roebuck, Mr. Cummings, and, no doubt, many others, eminent in the theory and practice of the arts, was only to prove what I said before they acknowledged it, that all condensers do more harm than good; and that when men of better judgment have constructed engines totally without condensers, as good or better than their own, they have just candour enough to admit the fact, and pride and avarice enough to claim them as their invention.

"There is, as your lordship has been abundantly informed, a valve placed in the passage allotted to conduct the steam, water, &c. from the cylinder to the condenser, which alternately opens and shuts this communication. I have to remark that, when the steam regulator, as in Newcomen's engine, opens to the cylinder, and at the same time causes the first jet of steam to discharge the water and air as above described, this valve in Mr. Watt's engine is then open to the condenser; and, was there nothing else, the steam would, as well as act on the piston, fly to the condenser, and being there destroyed at that end, if I may so say, would not move the piston at all; it was therefore necessary for Mr. Watt to introduce another valve, which he has done. But certain reasons, best known to himself, which the writer of this will not

pretend to suggest, induced him to omit giving your lordship and the court an account of it, though, as I have already noted, on the other valve his counsel were very profuse.

"This cunning valve, my lord, is like the injection water, smuggled into another part of the engine, and serves, as in the preceding case, to open and shut a communication. It happens, however, not to be the communication between the cylinder and the condenser, but, what is of much greater consequence, it opens and shuts the passage between the boiler and the condenser. I have materially to remark to your lordship respecting this valve, that it must be and is always shut during the time the steam regulator is open. How, then, is it possible, my lord, that this condenser can be cleansed as in Newcomen's, provided even the former objections did not exist?

"Thus, having aimed at as much perspicuity as possible, I hope, and am even confident, that your lordship, although no engineer, will perfectly understand what I have advanced, and be convinced of the necessity and practicability of giving a full and explicit description of this point also. I shall now proceed as proposed, with some detail on the nature, proportion, and situation of Mr. Wood's very ingenious and valuable application of a pump, or pumps, for the extraction of the water and uncondensed vapour, which would otherwise much impede the working of the engine, as Mr. Watt, for a wonder, has had the candour to declare in his specification.

"I will here entreat your lordship's patience, while I make a solemn protestation. I declare, and I challenge every scientific man to disprove it, that all the improvements which have yet fallen within my observation on Steam Engines, do wholly depend on the application of Mr. Wood's invention, *viz.* a pump; or, I will at least say, in a proportion of fifty to one, compared with the other additions made by Mr. Watt, with all his retinue of doctors, professors, philosophers, mathematicians, and mechanics

"Now for this pump, the ingenious invention of Mr. Wood. I repeat his name, as your lordship, having heard less about this pump on the present than on former occasions, might be at a loss to judge the cause of this declension, and on this account I shall be more plain on the subject. Much pains were taken on this trial to convince the court that proportion, lateral and altitudal situation, did not at all or not essentially signify: I will therefore confine what I have to say more directly to these points, with a small digression only to consider, as in the case of Mr. Gitty, some remarks from the eminent and ingenious Mr. Cummings, respecting this important article.

"My experience, my lord, obliges me to allow, that when a pump is introduced, or added to one of Newcomen's engines where there is no condenser, a trifling latitude in the size, over and above the real *maximum*, is of little moment, and may be exercised without much detriment to the engine; but I find, the closer we adhere to the smallest that is sufficient, the less the power of the engine is impeded by giving it motion.

"As the actual proportion the pump ought to have been to the cylinder must be the result of duly considering the engine both in a perfect and less perfect air-tight state, I will leave every engineer to study for himself, as Mr. Watt has done, and hasten to give my reasons why pumps, constructed without regard to proportions, &c. as above mentioned, will not answer in engines made with condensers.

"Suppose, my lord, I constructed an engine on the plan of Mr. Watt, with a steam cylinder exactly equal to one of Newcomen, to which I have annexed a pump of proper size; I should be very naturally led to make this second one from the same patterns; experience having shown me the propriety of its dimensions, and to save also the expense of new patterns, tools, &c. This done, I come to determine the size of my condenser. If I be at a loss in this, I go to Mr. Watt's specification; there I find not a word to help me. I then post off, perhaps from Manches

ter to Cornwall, to see a condenser; when I come there, I traverse the whole County in the character of a spy, and none will even permit me to enter their works, (and should I intrude without a licence, I should soon get myself expelled,) much less stop the engine, and disorganize the whole, to give me the knowledge I am seeking. My own reason, by this time more awake, makes this inference: that, provided I did succeed in meeting with a person friendly enough to suffer my scrutiny, I must of course pay the loss accruing from such an enterprise,—and, for an idea of this, I will refer your lordship to the observations already made on stopping engines. Just as wise, therefore, as when I started, I post back to Manchester, resolved to make a condenser of some sort. I begin by reflecting, not on the thing, for I know not what it is, but on its reputation; and if I chanced to recollect the high encomiums it received in the Courts of Westminster and London, I should be led to conclude, that were my engine all condenser, I could not fail of being on the right side of the question. Thus I determine my condenser shall be (what I have seen some made by Mr. Watt, at the Soho, Birmingham,) as large, or considerably larger than the steam cylinder of the engine for which it is intended. This would be at least twelve or twenty times the dimensions of my pump,—but say twelve times, for the sake of data; and suppose the engine completed, and ready for action: the consequence of this I will endeavour to make plain to your lordship. When the engine has been emptied of her air, and also the condenser, by what Mr. Watt's engineers call blowing through, the steam valve is opened, and the piston makes a stroke; then the discharge is made from the cylinder to the condenser by opening another valve. Now, let it be supposed that the uncondensible air or vapour which then fills the condenser, and is to be drawn out by a pump unequal in expansive force to one-twelfth part (and it is seldom less) of the steam's pressure on the piston. The air pump, which, I have already said, is only one-twelfth part of the contents of this condenser, makes one stroke also; but by this the

expansive force of the vapour can only be reduced one twelfth part, for it must take twelve strokes of this pump to reduce the vapour in the condenser to its least density; and, consequently, there will remain a resistance to the second stroke equal to $\frac{1}{12}$ of the force of the vapour mentioned; and to the next stroke $\frac{2}{12}$, and every continued stroke in this proportion; so that, in about thirteen strokes, this air and vapour would inevitably become as strong in the condenser as the steam; and, by thus restoring the equilibrium, of necessity stop the engine, although she had nothing but her own materials to carry, and those void of friction."

Making due allowance for the prejudiced feeling with which these remarks of Bramah's were written, arising from the successful rivalry of Watt, our readers will find much interesting information contained in them. They show clearly the insufficiency and obscurity of the specification in question.

Yet Mr. Watt was a truly wonderful man. His ideas were great, and many of his discoveries were successful beyond all previous conjecture. He has done more for art and commerce than any single individual ever known; but, whilst we admit all this, we must also say, few men would have put their names to many of the inventions which appear under his. All men have, at times, made discoveries, which they imagine to be excellent, but which prove otherwise: but few have put upon record so many absurd and impracticable schemes. What are we to say to his many rotative engines; to his six contrivances for regulating the motion of his engines; to his method of working engines by the alternate expansion and contraction of the steam? We answer, that the majority of them were impracticable, and some of them the most contemptible schemes that ever entered the brain of a projector. His mind seems to have been capable of any thing; but he was too inactive both in body and mind to set about satisfying himself of the true value of his inventions. Many years elapsed before he submitted his great scheme to the test of experiment; and, when the means *were* afforded, it was

three years before the experiment was completed. Long intervals passed over between his visits to Soho, even when many of his most important experiments were in progress. We cannot think with Playfair that "he never went either before or beyond the direct inference which could be drawn from an experiment; or that so great was his sagacity, that few bearings of that experiment were omitted or overlooked." We have shown, on the contrary, that not one half of his schemes answered, and that he, like all men, was liable to misconception and error.

From a wish to keep our description of Mr. Watt's discoveries as connected as we could, we have, until now, passed over the invention of Mr. Jonathan Hornblower, of Penrhyn, Cornwall, for which a patent was taken out in 1781. A full and detailed description is to be found in the first edition of Gregory's Mechanics. The following is a copy of his specification:—

"First,—I use two steam vessels, in which the steam is to act, and which in other steam engines are called cylinders. Secondly,—I employ the steam, after is has acted in the first vessel, to operate a second time in the other, by permitting it to expand itself, which I do by connecting the vessels together, and forming proper channels and apertures, whereby the steam shall, occasionally, go in and out of the said vessels. Thirdly,—I condense the steam by causing it to pass in contact with metallic substances, while water is applied to the opposite side. Fourthly,—to discharge the engine of the water employed to condense the steam, I suspend a column of water in a tube or vessel constructed for that purpose, on the principles of the barometer, the upper end having open communication with the steam vessels, and the lower end being immersed in a vessel of water. Fifthly,—to discharge the air which enters the steam vessels with the condensing water or otherwise, I introduce it into a separate vessel, whence it is protruded by the admission of steam. Sixthly.

—that the condensed vapour shall not remain in the steam vessel in which the steam is condensed, I collect it into another vessel, which has open communication with the steam vessels, and the water in the mine, reservoir, or river. Lastly,—in cases where the atmosphere is to be employed to act on the piston, I use a piston so constructed as to admit steam round its periphery, and in contact with the sides of the steam vessel, thereby to prevent the external air from passing in between the piston and the sides of the steam vessel."

This patent, like Mr. Watt's, conveys no idea of either form or dimensions; and we must therefore have recourse to other sources for more particulars respecting it. An enlarged account was inserted in "Gregory's Mechanics," but was afterwards omitted by the author, who, in a subsequent edition, makes the following remarks thereon.—"As I have been exposed to much calumny and misrepresentation for admitting that historic sketch into my work, I beg to remark that I did it *solely* from motives of benevolence. Till the time my second volume was preparing for the press, I knew nothing of Mr. Hornblower; but a friend of mine, on whose judgment I placed great reliance, who was well acquainted with Mr. Hornblower, and thought highly of his moral character, as well as of his mechanical skill, had a full persuasion that, through a series of unfortunate circumstances, he had never had justice done him, and urged me to allow Mr. Hornblower to tell his own story. I yielded to his solicitations, and in consequence exposed myself to the malevolence of certain writers, who, in one short note of ten lines,* published *four* positive, wilful falsehoods, for the honourable purpose of injuring my reputation. I, however, forgive them, although they treated me unjustly; and trust they will, ere now, have forgiven me for permitting an injured, though perhaps hasty, man, to defend his own cause and that of his family. He is now beyond the reach of those who wished to promote his welfare, as well as of those who,

* Edinburgh Review, vol. xiii. p. 327.

by unfairly depreciating his character, involved him in ruin. His latter years were rendered comfortable, not by the liberality of his countrymen, but by an opulent and scientific *Swede*, who knew how to appreciate and to reward his merit as an engineer.

"The principle of Hornblower's engine depended on his obtaining more power by a complicated force of steam than could be acquired by its simple action in the common mode. This is effected by the use of two cylinders of different capacities; and Mr. Hornblower, after inquiring into the effect of using steam according to each of these modes, compares the results together as follows. 'If 'we obtain the accumulated pressure by taking a mean of 'the extremes, we shall find Mr. Watt's application to be '$\frac{24+24+12}{3}=20$, leaving 12 lbs. at the termination of the stroke. 'The application of the principle in the present instance, 'by taking the mean of the two extremes, will be $\frac{24+18}{2}=21$, 'leaving 18 at the termination of the stroke; which, in 'point of advantage, in favour of the double cylinder, is 'as 3 to 2; a point of no small magnitude in the practical 'application of this principle, and which seems to have 'been overlooked by all those, who have taken up the 'subject.'"

The following description of this engine, (written by the inventor,) is copied from the "Encyclopædia Britannica." Let A and B represent two cylinders, of which A is the largest; a piston moves in each, having their rods, C and D, moving through collars at E and F. These cylinders may be supplied with steam from the boiler, by means of the square pipe G, which has a flange to connect it with the rest of the steam pipe. This square part is represented as branching off to both cylinders: *c* and *d* are two cocks, which have handles and tumblers as usual, worked by the plug-beam W. On the foreside of the cylinders is represented another communicating pipe, whose section is also square, or rectangular, having also two cocks, *a*, *b*. The pipe Y, immediately under the cock *b*, establishes a communication between the upper and lower parts of the cylinder B, by opening the cock *b*. There is a similar pipe

on the other side of the cylinder A, immediately under the cock *d*.

(*Hornblower's Engine.* 1781.)

When the cocks *c* and *a* are open, and the cocks *b* and *d* are shut, the steam from the boiler has free admission into the upper part of the small cylinder B, and the steam from the lower part of B has free admission into the upper part of the great cylinder A; but the upper part of each cylinder has no communication with its lower part.

From the bottom of the great cylinder proceeds the eduction pipe K, having a valve at its opening into the cylinder; it then bends downwards, and is connected with the condenser.

Lastly, the pump-rods cause the outer end of the beam to preponderate, so that the quiescent position of the beam is that represented in the figure, the pistons being at the top of the cylinder.

Suppose all the cocks open, and steam coming in copiously from the boiler, and no condensation going on in L, the steam must drive out all the air, and at last follow it through the valve Q. Now shut the cocks *b* and *d*, and open the escape valve of the condenser; the condensation will immediately commence, and draw off the steam from the lower part of the great cylinder. There is now no pressure on the under side of the piston of the great cylinder A, and it immediately descends. The communication Y, between the lower part of the cylinder B, and the upper part of the great cylinder A, being open, the steam will go from the lower part of B, into the space left by the descent of the piston of A. It must, therefore, expand, and its elasticity must diminish, and will no longer balance the pressure of the steam coming from the boiler, and pressing above the piston of B.

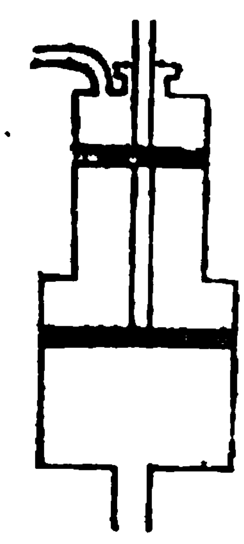
This piston, therefore, if not withheld by the beam, would descend till it came in equilibrio, from having steam of equal density above and below it. But it cannot descend so fast; for the cylinder A is larger than B, and the arch of the beam, at which the great piston is suspended, is no longer than the arm which supports the piston of B: therefore, when the piston of B has descended as far as the beam will permit it, the steam between the two pistons occupies a larger space than it did, when both pistons were at the top of their cylinders, and its density diminishes as its bulk increases. The steam beneath the small piston is, therefore, not a balance for the steam on the upper side of the same, and the piston B will act to depress the beam with all the difference of these pressures.

The slightest view of the subject must show the reader, that as the piston descends, the steam that is between them will grow continually rarer and less elastic, and that both pistons will draw the beam downwards. Suppose now, that each one had reached the bottom of its cylinder: shut

the cock *a*, and the eduction valve at the bottom of A, and open the cocks *b* and *d*. The communication being now established between the upper and lower part of each cylinder, their pistons will be pressed equally on the upper and lower surfaces; in this situation, therefore, nothing hinders the counterweight from raising the pistons to the top.

Suppose them arrived at the top: the cylinder B is at this time filled with steam of the ordinary density, and the cylinder A with an equal absolute quantity of steam, but expanded into a larger space. Shut the cocks *b* and *d*, and open the cock *a*, and the eduction valve at the bottom of A, the condensation will again operate, and cause the pistons to descend; and thus the operation may be repeated as long as steam is supplied; and one measure-full of the cylinder B of ordinary steam is expended during each working stroke.

Professor Robinson's mathematical investigation of the principles of this engine is extremely interesting. He demonstrates that the same effect only is produced as in Mr. Watt's expansion engine. We shall endeavour to show the same by an arithmetical calculation, as it will be thereby more generally comprehended.



We shall assume, for the sake of being more intelligible, that the cylinders are placed one above the other, as represented in the margin, the lower one being twice the area of the upper one, and the pistons connected by one rod; so that the external apparatus shall be at all times actuated by the united force exerted on both pistons.

We shall imagine the small piston to be 100 inches in area, and the larger one 200 inches; and, assuming the pressure to be 10 lbs. on the inch, the pressure on the smaller piston will be 1000 lbs., whilst that of the larger will be 2000 lbs.

Both pistons being at the top of their respective cylinders, let steam be admitted of the abovenamed density. The stroke will then be commenced with a force of about 2000 lbs. (not deducting friction,) because we have, in the

outset, the whole force of the larger piston, beneath which there is no resistance of its action; but the smaller piston, having steam of the pressure above as well as below it, is in equilibrio. But, as the pistons descend, the power of the greater one decreases, by the reduced resistance from the expansion of the steam contained between the two pistons, whilst the power of the smaller is increased by the steam from the boiler continuing to act on it with the force of 10 lbs. on the inch, whilst the steam underneath it is gradually expanding into the larger cylinder, and consequently becoming reduced in its density. The following table, extracted from Rees's Encyclopædia, will show the variations in the power at certain parts of the stroke.

Descending power of the great piston.	Descending power of the small piston.	Combined powers of both pistons.
lbs.	*lbs.*	*lbs*
At first, the power will be 2000	 0	At first.. 2000
In consequence of the pressure of 10 lbs. per inch on its upper surface, and no pressure beneath.	Because the piston is in equilibrio, having 1000 lbs. pressing upwards. & 1000 lbs. downwards.	
At one-fourth of the descent the power will have diminished by regular decrements to 1600	 200	 1800
Because the steam between the two pistons must occupy ¾ths of the smaller cylinder, and ¼th of the great cylinder, which is a space equal to 1 and ¼th of the original space which it filled; therefore, the space will be as 5 to 4, and if the density be as the inverse proportion of the space, the pressure on the great piston must be ⅘ of 2000=1600.	Because the equilibrium does not continue, and at ¼th of the descent, the pressure under the small piston is reduced by the expansion of the steam between the pistons to ⅘ of 1000=800, while the pressure above the piston continues to be 1000. The power is, therefore, 1000 — 800=200.	
At one-half of the descent the power will be diminished to 1333⅓	.... 333⅓	.... 1666⅔
Because at this point the steam between the pistons occupies one-half of the small cylinder, and one-half of the large one, which is a space equal to 1½ of what it filled at the commencement; the spaces will therefore be 6 to 4, and the pressure on the great piston as 4 to 6, or ⅔ds of 2000=1333⅓.	Because the pressure beneath is diminished by the increased rarity of the steam to two thirds of 1000=666⅔, while the downward pressure continues to be 1000. The power is, therefore, 1000 — 666⅔=333⅓.	
Carry forward 4933⅓	.... 533⅓	.... 5466⅔

Descending power of the great piston.	Descending power of the small piston.	Combined powers of both pistons.
lbs.	*lbs.*	*lbs.*
Brought forward ....$4933\frac{1}{3}$	.... $533\frac{1}{3}$	.... $5466\frac{2}{3}$
At three-fourths of the descent the power will only be ....$1142\frac{6}{7}$	.... $428\frac{4}{7}$	.... $1571\frac{3}{7}$
Because the steam must now occupy $\frac{1}{4}$th of the small cylinder, and $\frac{3}{4}$ths of the large cylinder, which is a space equal to $1\frac{3}{4}$ths of the original space. Thus the spaces will be 7 to 4, and the pressure on the great piston four-sevenths of 2000 $=1142\frac{6}{7}$.	Because the pressure beneath is reduced by the rarity of the air to four-sevenths of $1000=571\frac{3}{7}$. Therefore the power is $1000-571\frac{3}{7}=428\frac{4}{7}$.	
At the bottom of the cylinder the power will be..1000	 500	 1500
Because the steam must occupy the whole of the large cylinder, a space equal to twice the small cylinder, which it at first filled. The pressure will therefore be $\frac{1}{2}$ of $2000=1000$.	Because the steam beneath the piston is reduced to $\frac{1}{2}$ of its pressure, or 500, which, deducted from 1000, leaves 500.	
Sum of the powers exerted by the great piston in its descent 7076	Sum of the powers of the small piston . 1461	Sum of the combined powers..8537

Now, if Mr. Watt's principle of expansion were used in a cylinder of the same area as the larger one in this instance, and the pressure of steam the same at the commencement, namely, 10 lbs. on the inch, until one-half of the stroke be completed, and the remainder be effected by the expansion of the steam already contained in the cylinder, the power will be—

At the beginning	2000 lbs.
At one-fourth	2000
At one-half	2000
At three-fourths	$1333\frac{1}{3}$
At the bottom	1000
Total effect............	$8333\frac{1}{3}$

Hence it will appear that the difference between the effect of the two principles is very trifling; but even this

difference would not exist, if recourse were had to fluxions, instead of common arithmetic; because by the latter it is assumed that the change in the two effects, named at any two points, has only taken place at that last named, and consequently that the force up to that point had continued the same as the preceding one. For instance, the force on the larger piston of Mr. Hornblower's engine is stated to be at one-fourth of the stroke, and from thence to the half stroke, 1600 lbs.; but this is not the fact, for, from the quarter to the half stroke, the force is gradually diminishing from 1600 to 1333⅓. The minutest subdivisions would only be an approximation to accuracy. Fluxions are the only method of obtaining correctly the sum total of constantly increasing or decreasing quantities.

In this calculation of the power of Mr. Watt's engine, a less number of points have been taken than ought to have been; for although five are taken, in common with Mr. Hornblower's, yet two of them are when the cylinder of Mr. Watt is in communication with the boiler; whereas the comparison ought to have been made by taking five points during the last half of the stroke of each engine. By this method it would have been seen that a very trifling difference in the total effects of each would have resulted.

In confirmation of these calculations it may be stated, that Mr. Hornblower's engine was not found in practice, to exceed in effect the expansion engine of Mr. Watt. He erected an engine in 1792, at Tin Croft Mine, in Cornwall, which, it appears, did not perform work equal to an engine of Messrs. Boulton and Watt, which consumed the same quantity of coals.

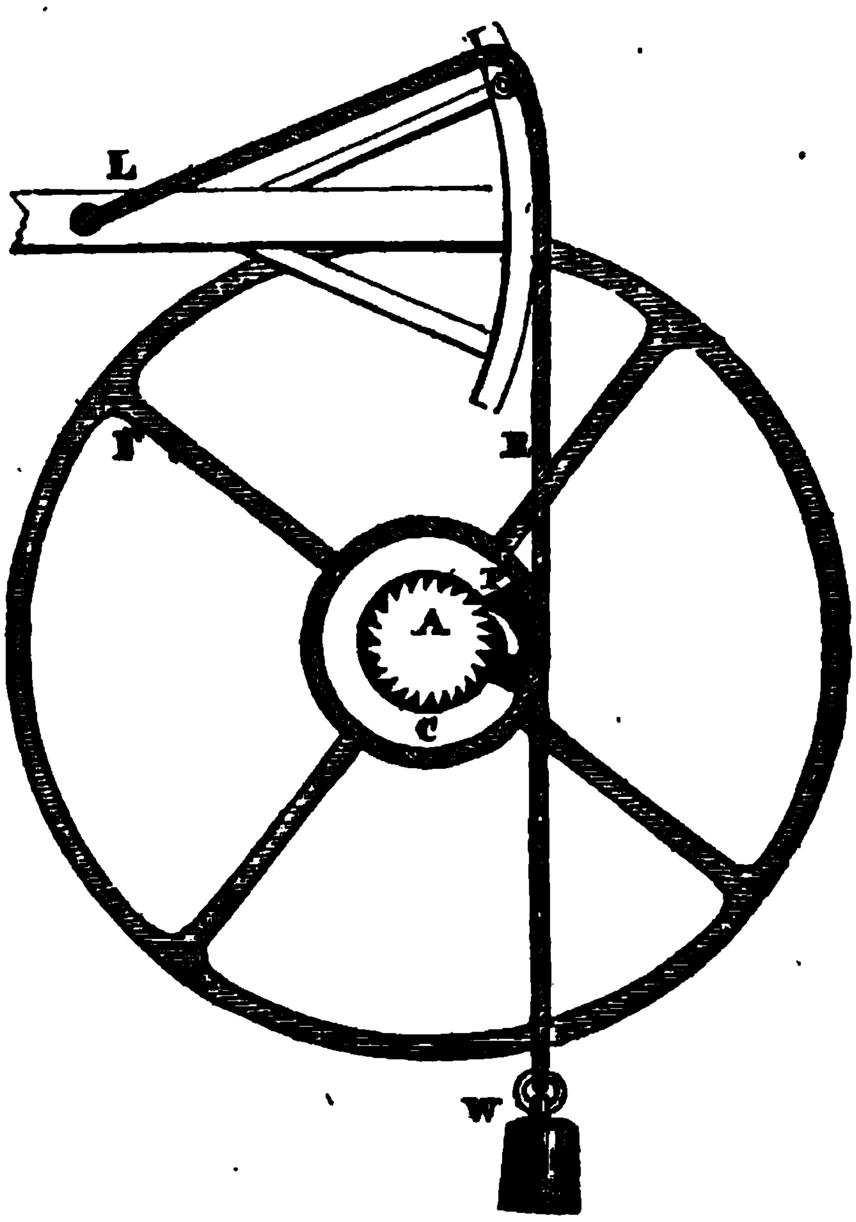
We shall now proceed to the consideration of the next invention that presents itself in chronological order, which is a Rotative Engine by Mr. Cooke, a drawing and description of which are to be found in the Transactions of the Royal Irish Academy, 1787. We subjoin a description thereof.

(Cooke's Rotative Engine. 1787.)

On the circumference of a wheel eight vanes or flaps are attached by joints, which are formed to open somewhat more than half of their circumference. During the revolution of the wheel, the vanes being first opened by their own gravity, are afterwards kept to fill the channel by the pressure of the steam. *c c c* are the valves or flaps; *b* is the tube which admits steam from the boiler; *a* a tube leading to the condenser. *k k f* is the case in which the wheel *k k* is enclosed as high as the dotted line; this case is to be steam-tight. The wheel being supposed in the situation in the figure, the valves prevent any communication between the boiler and condenser. Steam is now admitted at *b*, and, pressing on *c c*, forces them forward in its passage to the condenser, and produces movement. The condenser is worked by a crank in the axis, and a rod *d* is extended from it, which keeps a constant vacuum in that hal. of the steam case :—"by this means a power is added to the steam equal to the weight of the atmosphere; so that, when the force of the steam is only equal to the pressure

of the atmosphere, and the valves are six inches square, the wheel will be forced round by a power equal to 531¼ lbs. placed on its circumference." The construction of this machine we need hardly say would be impracticable. Friction out of the question, the imperfection of the mechanism, and the clumsiness of the whole engine, are too apparent to need any detail.

Mr. Thomas Burgess obtained a patent, in 1789, for a method of producing a rotary motion from the action of an alternate movement. We are induced, from the probability that few of our readers are acquainted with it, to give it a place here.



(*Burgess's Rotary Motion.* 1789.)

Upon an axis A, to which the rotary motion is to be communicated, a collar C is accurately fitted, so as to turn freely thereupon, and so secured in its place as to prevent its sliding sideways; round the collar a chain or rope R is to be wound; one end of the rope is made fast to the

lever L of a steam engine, or other alternating moving power, which motion may be horizontal, vertical, or in any other direction: to the other end of the rope a weight W is suspended, which is to draw the collar C back, in the interval between each stroke or impulse of the moving power. Inside of the barrel or collar C is fixed a pall or catch, P, which falls by its own gravity into the notches of the axle A, so that, when it is acted upon by the moving power in one direction, the axis A becomes locked to the collar, and the fly wheel F is forced into a rotary motion. When the action is reversed by the alternating motion of the lever L, the collar is released and runs back, the pall sliding over the notches in the axis without impediment, the original rotary motion continuing in the fly wheel, by the impetus given it at every alternate stroke of the lever.

This machine needs no comment; it is infinitely inferior to the crank which was in use prior to the date of this patent: it is, notwithstanding, very ingenious; and, fifteen or twenty years sooner, might have been considered as a convenient and useful method of obtaining the desired end.

In the year 1790, Mr. J. Bramah, of Piccadilly, (author of the pamphlet addressed to Chief Justice Eyre, from which we have made copious extracts,) and Mr. Thomas Dickinson, of Bedworth Close, County of Warwick, jointly obtained a patent for three rotative engines.

In the subjoined engraving, fig. 1. represents the plan of one of these engines, and fig. 2, a section. A A and B B show the ends of two short cylinders or rings of different diameters, one placed in the centre of the other. C is the channel or circular groove, formed between the two circles. The ends of the cylinder or ring B B are shut up by two flat plates D D, as shown in the section; to these plates is joined an axis or spindle E E, which axis or spindle passes through the ends or caps F F, which enclose the ends of the cylinder or ring A A, and which is made air-tight by means of a stuffing box in the usual way. By this axis or spindle the cylinder or ring B B may be

(*Bramah and Dickinson's Rotative Engine.* 1790.)

turned round from without, any external power being applied for that purpose; or this axis or spindle may be applied to give motion to any other machine, when the cylinder B B is turned round by any power or force acting from within. In the cylinder or ring B B are fixed two sliders, G G, crossing each other at right angles in the centre, where they are notched or half spliced, so far as to allow them to slide backwards and forwards, as much, at least, as the diameter of the channel or groove C. The length of each of these sliders is equal to the diameter of the cylinder or ring B B, and one diameter of the channel or groove C, and the width is equal to the height of the channel or groove C; so that the points which perforate the extremity of the cylinder or ring B B, when they are pushed out into the channel or groove, may entirely fill the same, similar to a piston working in a common cylinder; in order that, when the cylinder B B is turned round, the channel or groove may be by that part of the slider totally swept or emptied. In this channel or groove is fixed the partition H, which fills the same in that part, and, by its being fitted against the periphery of the wheel B B, prevents the passage of any fluid that way round the channel, when the caps or ends are screwed down. On each side of the partition H is fixed a rib I I, or piece of such a shape as to perfectly fit the circle B B, one quarter of its circumference, between the dotted lines 1, 2; and the remaining part is continued in a shape inclining to the circle of the greater cylinder A A, with which it forms an easy juncture at the quartile points, 3, 4. When the cylinders B B, with the sliders, are turned round in either direction, the inclined parts of the ribs I I force the opposite end of the sliders G G, successively into their channel or groove, where they are obliged to remain during one quarter of the revolution, being kept in that position by the circular part of the rib between 1 and 2. K M are two pipes of any required diameter, which may be inserted into the channel or groove, in any direction the situation of the machine may require, between the points H 3 and H 4. The sliders are rendered sufficiently tight at their

junction with the channel, by means of oakum or any other flexible material being forced into the cavities made for that purpose at the parts L L L, and also the partition H in the same way. The cylinder or ring B B, being thus armed with the sliders, and the caps or ends, F F, screwed on by the flanches at A A, the machine is complete, and ready for action. Now, supposing that through the pipe K a shaft of water, steam, or any other fluid, from any considerable height, is admitted into the channel or groove C, it would immediately force against the slider projected in the channel as at N, and also against the fixed partition H; which partition, preventing its passage that way to the evacuation pipe M, where the spent water is discharged, the next slider in succession has passed or covered the junction of the ascending pipe K, so that each successive slider receives the pressure before it is done acting on the former; by this means a uniform rotation is maintained in the cylinder B B, and its velocity will be equal to the descent of the water in the pipe K, and its force equal to the specific gravity of the same. Thus this machine may be worked by steam, condensed air, wind, or any other elastic or gravitating fluid, for the purpose of working mills, or any other kind of machine or engine whatsoever, they being properly connected with the axis or spindle E E; and when any power is externally applied to the said axis, which may turn the machine in any direction, it becomes a complete pump; possessing all the properties of every other sort of hydraulic engine whatsoever, by applying the pipes K and M accordingly; and it has also much advantage over every other kind of pump, as the fluid pumped is kept in constant motion both in the suction and ascending pipes. This machine may be fixed either in a horizontal or vertical direction."*

It will be perceived that the machine, for which Mr. Job Rider recently obtained a patent, resembles this in principle. The point in which Mr. Rider's differs from it, is in his sliders being more in number, and, instead of

* Specification of Patent

crossing each other, are formed of shorter plates not reaching to the axis. The excessive friction of this machine would be a sufficient reason for its abandonment; besides which, the cross sliders, G G, would in time become so worn at their ends, that the ribs, I I, would not be able to force them against that part of the cylinder opposite the projection H, so as to stop the passage of the steam.

In the annexed engravings, fig. 1. represents another plan of a rotative engine in the same patent, where the sliders are stationed in the periphery of the outer cylinder, and the water, steam, or other fluid, passes first into a smaller or inner cylinder, previously to its producing its effect in the channel or groove, as in the other example. A is the end of a hollow smaller cylinder, placed in the centre of the larger cylinder B; the cylinder A is fixed on an axis or spindle C, as in the section. D D is the channel or groove, formed between the outer surface of the cylinder A, and the inner surface of the cylinder B; to the cylinder A is fixed a wing or fan E, of a projection sufficient to fill and act in the channel D D as a piston, when A is turned round by the axis or spindle C, so as to sweep the contents of the channel; or, when any force is applied on one side of its surface, it will cause the cylinder A, and the axis or spindle C, to be turned round. The cylinder A is left open at both ends, which pass through the end plates into the caps, and is fitted water-tight in the junctions. In or about the middle of the cylinder A is a chamber or partition, which divides the upper end from the lower; H H are two sliders, stationed at opposite points in the periphery of the outer cylinder B, where there are cells projected as at I I, to receive them and allow their motion. These sliders are moved by the small spindles K K passing through stuffing boxes in the usual way. They are ultimately opened and shut by half the rotation of the inner cylinder, by means of a wheel with an eccentric groove fixed on the axis, as L L. In this groove move two friction wheels, which being joined to the sliders by a connecting bar, the sliders H H are opened and shut, by the axis C turning round, so that one

FIG. 1.)

(FIG. 2.)

(*Bramah and Dickinson's Engine.* 1790.)

of the sliders H H is always close shut against the cylinder A, whilst the other is opening to let the wing or fan pass, which is again shut before the passive slider begins its motion. The machine being thus complete, suppose that, at a pipe O, a current of water, steam, or other fluid having force, was admitted into the cap whilst the machine is in its present position, it would immediately fall into the upper cavity of the cylinder A, and, passing through the aperture into the channel D, would press against the wing or fan E, on the one side, and against one of the sliders H H, on the other; which slider not giving way would cause the wing or fan E to recede, and turn round the cylinder A with its axis C; which axis, turning the wheel with the groove L L, would cause the opposite slider to begin its motion; so that by the time the wing or fan E reaches the station of the slider, it is totally drawn back into its cell, so as to permit the wing or fan E to pass without interruption; and, by the continued motion of the machine, the slider is again shut, before that slider on

which the fluid is pressing begins to move; so that, when the first slider, against which the water or fluid is still pressing, is opened, the pressure is then the same between the other slider and the wing or fan E; and the spent fluid between the two sliders immediately rushes through the lower aperture into the bottom of the cylinder A, and is carried off in that way to the open air: thus a uniform rotation will be maintained, as in the former example.*

This engine is remarkable for simplicity; and if a metallic packing had been at that time known, it might have approximated to a useful rotative engine. As it was, it would be impossible to make hempen packing pass over the grooves for the sliders, without being speedily torn out; and also it would be very difficult, if not absolutely impossible, to keep the sliders H against the internal cylinder A, as at each stroke the sliders would rebound from it; and not being kept close by the force of the steam, as in many rotative engines, would soon become loose at the joints, and thereby ineffective.

The following diagram represents another method by which Messrs. Bramah and Dickinson purposed to obtain a rotative motion. A is a smaller wheel or cylinder, armed with cross sliders, fixed in a larger one B, but, instead of its axis being stationed in the centre of B, as in the previous instances, it is moved as much eccentric as to cause the periphery of A to rub against the side of B, as at C; this causes the channel or groove D D D, to be formed of the shape which appears in the figure. The inner surface of the wheel or ring B is not perfectly cylindrical, but is a curve of such a shape as would be described by the points of the sliders E F being of equal length in the revolution of the wheel A; or, in other words, of such a shape as would occasion all the four points of the said sliders to be in constant contact therewith. The dotted lines G G show two grooves or cavities, through which the water, steam, or other fluid, contained between the point C and either of the apertures of the pipes H and

* Repertory of Arts.

I, passes into either of the said pipes; which water, steam, or other fluid, would otherwise be pinned up by the slider, and stop the motion of the machine when turned in either direction.*

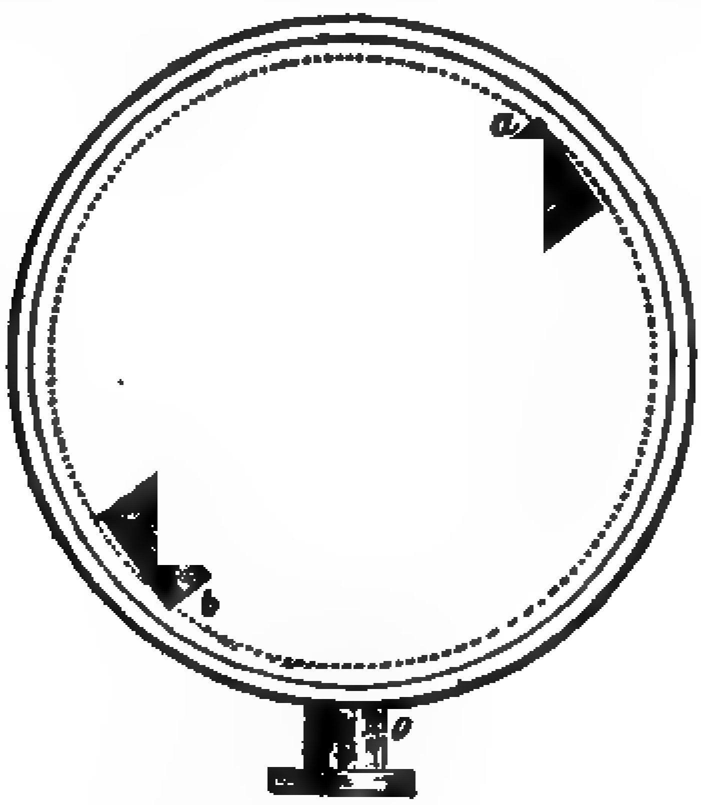
(*Bramah and Dickinson's Engine.* 1790.)

This machine would be liable to the same objections as the first. On the whole, these contrivances display great ingenuity, and may be justly considered to rank as high as any that have since been proposed; indeed, there are few rotative engines which do not, in principle, somewhat resemble these; therefore we conclude that, had the genius of the inventor or inventors been exercised when mechanical experience had been more advanced, they might in all probability have effected that, which is so great a desideratum among modern engineers.

Mr. James Sadler, of Oxford, in 1791, obtained a patent for a rotative engine, which the following drawing and description may serve to illustrate. The steam generated in the boiler is conveyed through the pipe *c*, into the spindle or axis of the rotative cylinder *a b*; which is made

* Specification of Patent.

steam-tight by working in a stuffing-box. The steam passes along the arms of the revolving cylinder, nearly to its ends, where it meets a jet of cold water, introduced from the hollow axis by the small pipe *x x*; this condensing water falls from the revolving cylinder into the bottom of the case, whence it is conveyed through a pipe, and is discharged by openings made in the ends or sides of another cylinder, moveable in a horizontal direction, giving it a rotatory movement, in the same manner as Barker's mill. The jet of cold water, from the pipes *x x*, having condensed the steam, produces a re-action, and the cylinder *a b* acquires a rotative movement. The inner case is steam-tight; and the outer case serves the same purpose with the jacket in the reciprocating engines. Another mode of action is suggested by Mr. Sadler to be had by filling the case (in which the arms revolve) with steam, which would cause them to revolve by the pressure it would produce in being condensed in entering the arms.



(Sadler's Engine. 1791.*)*

This engine is Hero's in another form, and, like it, an ineffective toy.

The Rev. Edward Cartwright's scheme, for which he obtained a patent in 1797, was very ingenious His object was to procure a tight piston, and a condenser in which the steam was exposed to a large surface of water.

The condensation is effected by two metal cylinders, placed one within the other, and having cold water flowing through the inner one, and inclosing the outer one. Thus the steam is exposed to the greatest possible surface in a thin sheet. Mr. Cartwright likewise has a valve in the piston, by which a constant communication is kept up between the cylinder and condenser, on either side of the piston; so that any steam improperly entering the cylinder, is instantly exposed to the condenser, whether in the ascending or descending stroke. By this contrivance, steam that may escape past the piston will be immediately condensed, and the vacuum thereby preserved. This was considered to be a decided advantage over the general mode of arranging the valves, which does not always provide for the restoration of a vacuum destroyed by the imperfection of the packing.

"In the following figure, the piston *b* moving in the cylinder *a*, has its rod prolonged downwards; another piston *d* is attached to it, moving in the cylinder *c*, and which may be also considered as a prolongation of the steam cylinder. The steam cylinder is attached by the pipe *g* to the condenser, placed in cold water, formed of two concentric circular vessels, between which the steam is admitted in a thin sheet, and is condensed by coming in contact with the cold sides of the condensing vessel. The water of condensation falls into the pipe *e*. To the bottom of the cylinder *i*, a pipe *m* is carried into a box *n*, having a float-ball *o*, which opens and shuts the valve *p*, communicating with the atmosphere: a pipe *q* is also fitted to the box. There is a valve placed at *i*, opening into the cylinder *c*; another at *n*, also opening upwards. The pipe *s* conveys steam from the boiler into the cylinder, which may be shut by the fall of the clack *r*. *k* is a valve made in the piston *b*.

"In the figure, the piston *b* is shown as descending by

(*Cartwright's Engine.* 1797.)

the elasticity of the steam flowing from the boiler through *s*; the piston *d*, being attached to the same rod, is also descending. When the piston *b* reaches the bottom of the cylinder *a*, the tail or spindle of the valve *k* being pressed upwards, opens the valve, and forms a communication between the upper side of the piston and the condenser; at the same moment the valve *r* is pressed into its seat by

the descent of the cross arm on the piston, which prevents the further admission of steam from the boiler; this allows the piston to be drawn up to the top of the cylinder, by the momentum of the fly-wheel *x*, in a non-resisting medium. The piston *d* is also drawn up to the top of *c*, and the valve *i* is raised by the condensed water and air, which have accumulated in *e*, and in the condenser *g*. At the moment when the piston has reached the top of the cylinder, the valve *k* is pressed into its place by the pin or tail striking the cylinder cover; and at the same time the piston *b* striking the tail of the valve *r*, opens it; a communication is again established between the boiler and piston, and it is forced to the bottom as before. By the descent of the piston *d*, the water and air which were under it in the cylinder *c*, being prevented from returning into the condensing cylinder by the valve under *i*, are driven up the pipe *m*, in the box *n*, and are conveyed into the boiler again through the pipe *q*. The air rises above the water in *a*, and when, by its accumulation, its pressure is increased, it presses the float *o* downwards; this opens the valve *p*, and allows it to escape into the atmosphere."

This most ingenious machine, it appears, was tried first at Cleveland Street, Mary-le-bonne, and afterwards at Horsleydown, at both of which places it is said to have given great satisfaction. These trials must have been much more decisive than any opinion; and although we have not been able to ascertain further respecting the success of the engines when put in practice, than the simple fact of their having been approved of by the respective proprietors, our own judgment warrants a conclusion, that this plan is admirably adapted to be applied where a small engine is necessary. The mode of condensation adopted by Mr. Cartwright was considered to be liable to great objection previously to experiment; so much so, that one of the greatest engineers this country ever produced, was heard to state it as his opinion, that "were a pipe to be laid across the Thames, the condensation would not be quick enough to work a steam engine with its full effect." It was shown, however, when tried, that

this opinion was incorrect, as the condensation was very rapid, and the vacuum tolerably good.

Not the least ingenious part of Mr. Cartwright's patent was the metallic piston, which has been of late years very generally used. Though this kind of piston is now somewhat differently modified from his, yet he is entitled to the merit of having first introduced it into use. It has been found to answer extremely well, and frequently works for years without needing any attention, and merely requiring to be kept well greased.

(*Cartwright's Piston.* 1797.)

Mr. Cartwright's consists of two rings of brass, of the full size of the cylinder, which are cut into segments, as shewn at *l l l*, and laid one above the other, so as to *break joint*. The joints, therefore, in the under ring are shewn by dotted lines in the figure; and being thus disposed, the two rings are secured in their places by a top and bottom plate, to which the piston rod is fixed. The segments are pushed against the cylinder by steel springs, shewn at *n n*.

A rotative engine is also described in this specification; but we apprehend that practical difficulties would prevent its being ever carried into execution. The axis D in the following cut is fixed in an internal drum or cylinder, to the periphery of which are attached the three pistons H H H, which entirely fill the channel formed between the interior and exterior cylinders; *d d* are two valves or flaps, which, when shut into the cavities, form a portion of the exterior cylinder, but when open (as drawn) serve as a *butment* to re-

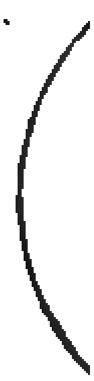
ceive the action of the steam, which being introduced from the boiler through the pipe E, and consequently between the open flap *d*, and one of the pistons H, when the same piston has passed the lower flap *d*, it also opens and receives the action of the steam, which enters through G, so that the flaps may at all times relieve each other, without interrupting the operation. Mr. Cartwright does not describe how these pistons and valves are to be made, or, being made, how they are to be kept tight. Two methods only are known, namely, hempen or metallic packing; the first would be soon destroyed by the holes in the sides of the exterior cylinders, formed for a communication with the boiler and condenser, by means of the pipes E F G, and metallic packing would here require too much nicety and expense to be generally useful. But this is not all; the friction of the interior drum would far exceed that of the common engine, which it was intended to supersede; and the flaps, *d d*, would be liable to knock themselves to pieces by the frequent striking against the drum, as they are thrown forward by the external machinery.

(Cartwright's Rotative Engine. 1797).

Mr. Jonathan Hornblower's Rotative Engine (for which a patent was obtained in 1798) displays much ingenuity. The vessel in which the steam operates consists of a hollow cylinder, composed of two unequal parts, the smaller section of which is screwed off and on, for the purpose of rectifying and repairing the internal structure. These parts are cast separate, and then screwed together, firm and close, by means of flanches. They are then covered with lids turned also true, and form a figure resembling a drum. A Z are two tubes, which pass through the central openings in the lids of the drum, meeting each other at B. *a b c d*, are the interior limits of those tubes, on the inside of the drum, which are considerably larger than at A Z in their diameters; the use of which is, that there shall be a proper cavity at *e f g h*, to receive a packing of tow and grease, or any other materials answering the purpose, between that particular part and the end of the drum; and also the frames of the diaphragms C C, may have the firmer holding to the hollow axles or tubes at D, D, leaving the parts of the diaphragm pendent at *i k*. The dotted lines show the interior limits of the drum, when the diaphragms are in their places; between which and the extremities of the diaphragms there is a proper rabbet to receive the packing, and between the pendent part of the diaphragms and the central hollow tube about which it revolves. This rabbet is formed by means of plates of metal, screwed on to the frame of the diaphragms, having their edges nearly in contact with the inner surface of the drum, and will be found accessible to repair or renew the packing, when the pannel which constitutes a part of the drum is removed. The parts *e f g h* may also be repaired at the same time, by means of removing two screws at each end of the hollow tube. The diaphragms (which are here standing in opposite directions) may therefore freely revolve the one after the other, or one may move whilst the other remains stationary. The tubes to which they are attached will have their concentricity preserved by means of the solid axle within the hollow one at E, fig. 2, which is fixed to the

end of the tube Z, and passes closely through a hole in the end of the tube A, till it reaches the extremity; where, by means of a second collar, its central position is critically maintained. The two diaphragms are hollow within, and hold communication with the cavities of their respective tubes which compose the hollow axes; and these communications are made by oblong openings where the diaphragms and tube are connected at D D.

(FIG. 1.) (FIG. 2.)



C. B

(*Hornblower's Rotative Engine.* 1798.)

The diaphragms are completed when the plates are screwed on; in these plates are fixed two valves G, opposite to which are two others, one in each diaphragm, so corresponding, that at the opening of one the other is closed, and *vice versa*. These valves are balanced and held in trunnions, so that, in every situation of the diaphragms, they may uniformly obey the impulse by which they are opened and shut; the manner in which that is effected is as follows:—the two diaphragms widen towards their extremities in the manner of radii, (see fig. 2,) and may therefore be brought into sufficient contact to force open the valves by means of prominences on them for the purpose.

To explain the manner in which the diaphragms are wrought upon, when in their proper place, let fig. 2. represent one end of the hollow cylinder or drum, and the central circles exhibit the hollow tubes or axles already explained. The two diverging parts are the ends of the diaphragms, and are packed as before mentioned; now, these diaphragms are hollow within, and if we consider one of them to be constantly supplied with steam by means of the hollow tube to which it is connected, and the other continually holding communication with the condensing water, the consequence will be, when steam is admitted through a valve into the lesser apartment of the drum, and another valve opens from the empty diaphragms into the larger apartment, that the diaphragms will recede from each other, with all the force of the steam between them; but if, by proper prevention, they can move only in one direction, it is plain that the one will remain stationary till overtaken by the other; their junction will then shift the valves into contrary positions by means of the prominent parts in them for that purpose, and the apartment, before filled with steam, instantly becoming empty, the diaphragm which was before stationary now becomes active, and the momentum of the former may, in effect, be considered as transferred to the latter. There being, therefore, in these parts of the machine, a continual motion, by rapidly succeeding each other in a circular direction,

their respective axles on which they turn, and which communicate motion to other machinery without the drum, are influenced in the same manner, agreeably to the main principles herein primarily set forth.

In order that the steam shall have a power of turning the diaphragms only in one direction, let fig. 1. represent one of the lids of the drum, having the side that is faced true on the opposite direction to that exhibited in the drawing; in this is a circular channel, G G, and a projecting ring P, which serves as a perpetual fulcrum to support the two levers, C, D, that occasionally revolve in the channel, and act as detents. The outer boundary of the channel also acts as a fulcrum to the extremity of the two levers at their thick ends; so that, when they are acted upon, from their connexion with the axles turning them to the right hand, by means of a strong collar E, there will be no impediment to their freely revolving in the circular channel; but, when the axles strain upon the small ends of the levers in a contrary direction, they instantly become fixed so firmly between the two boundaries of the channel, as effectually to resist the whole force of the machine. To provide against the least retrograde motion whatever, when the levers may be partly worn from friction, they are furnished with springs between them and the outer extremity of the channel, so that the two bearing points may at least touch their respective fulcrums.*

In this specification, the method by which a continuous circular motion is obtained, by the alternate action of the diaphragms, is not shown. This may be obtained by an apparatus similar to that represented at fig. 1., or by pulls attached to the outer end of the shaft and tube, acting upon a ratchet, which is fixed to the fly-wheel shaft; in the latter case, the palls would successively take hold of the ratchet as the other had ceased to act, and turn round the fly wheel, whilst the stationary are held firmly by the apparatus (fig. 1.) at the other end of the drum.

The objection to this machine appears to be that the

* Specification of Patent.

two diaphragms *c* would soon destroy each other; for whilst one remained stationary, the other, having no check, would strike forcibly against it: now, to retard this check would be to produce an irregular motion; because as the motion is communicated directly to the external machinery, any decrease in the speed of the diaphragm would also produce a decrease of speed in the machine throughout; and if the speed of the diaphragm be kept up, it would strike violently against that one which is at rest.

Mr. Matthew Murray, of Leeds, a gentleman whose name will be familiar to most of our readers as a steam engine manufacturer of celebrity, obtained a patent, in 1799, for saving fuel and lessening the expense of engines. He proposed to effect the first object, by having a small cylinder upon the boiler, to which he fitted a piston and rack: this rack worked a wheel upon a spindle, which spindle passed through the chimney, where was a damper, which had free liberty to turn round. As the steam increased in the boiler beyond the necessary force, it forced up this piston and rack, which acting upon the spindle, closed or partially closed the damper, and thereby lessened the draught of the fire, by which the consumption of the coal was reduced, until the superfluous steam was wrought out of the boiler, when a weight, which had been wound up by the rise of the piston, descended, and allowed the damper to return to its former position.

The other object, namely, decrease of cost, we will give in the words of the specification. "I cause the steam or atmosphere to act upon pistons moving in long pipes or cylinders, lying in a horizontal direction. These pipes may be square or round, and of any length required, but must lie in a horizontal direction, which is the principle here stated. By which contrivance, a more convenient motion can be applied to mill work, and a much longer stroke can be obtained than in the usual way.

"Next, I cause the pistons moving in the above pipes or cylinders, by their reciprocating motion, to produce a circular or rotative motion of equal power, by means of screws, racks, and wheels, applied in such a manner as to cause the power of the engine to fix alternately the wheels

necessary for producing motion, in perpendicular or horizontal directions."

(*Murray's Regulating Apparatus to Furnaces.* 1799.)

Figs. 1. and 2. are two horizontal cylinders, containing pistons; M M the piston rods. Figs. 1 1, inlets for the steam from the boiler and atmosphere; 2 2, outlets for the condensed steam or atmosphere; N, a roller for bearing the piston. These pipes or cylinders must be firmly fixed down to a stone platform, or iron cistern, or any kind of firm and secure fixing.

O (fig. 1. and 2.) is a rack, fixed to the piston rod M, and moving upon the roller P; Q is a socket wheel with teeth, working in the rack O; the inside of the socket wheel Q is screwed to fit the *middle* of the axletree; R 1, and R 2, (fig. 1.) are plain wheels, put loose on the *square* of the axletree; at S 1 and S 2 are tooth wheels, put loose upon the *round* part of the axletree. T T are plain wheels, acting as abutments, put fast upon the axletree. On an axletree or rotative shaft, for giving motion to the mill work, are fixed the wheels V and W; X a small fly wheel, for regulating the motion.

Now the effect or motion of this machine is, that when the piston, and piston rod, and rack O, are impelled by the steam or atmosphere in the direction of the arrow, the socket wheel Q, turns upon the screwed part of the axletree, and with its ends presses (by the force or power of the engine) the loose wheel S 1 between the wheels R and T, by which means, the wheel V is turned with the same velocity as the screwed wheel Q, while the wheel S 2 is at liberty upon the axle; in which situation the whole continues, till the piston arrives at the end of the long pipe or cylinder. When the piston is changing motion and going in the contrary direction to the arrow, the rack O turns the wheel Q in the opposite direction, sets at liberty, by the former means, the wheel S 1, and fastens the wheel S 2, which gives the same motion to the wheel W, by means of the intermediate wheel B.*

Nearly the same objections may be urged against this method of getting a revolving motion, as have been stated to exist against Mr. Hornblower's revolving engine;

* Repertory of the Arts

namely, that the motion of the piston must be uniform throughout, because any decrease in the speed of the piston must also decrease the speed of the fly wheel. Therefore, as the motion of the fly wheel must necessarily be uniform, it follows that the sudden reversion of the stroke of the piston must cause a violent shock to the whole machine.

(*Murdock's Engine.* 1799.)

Mr. W. Murdock, of Redruth, in Cornwall, obtained a patent in 1799, for a better method of boring cylinders, and for casting the steam case of Watt's engine in one entire piece, to which the top and bottom of the cylinder are attached. He also proposed to cast the cylinder and steam case of one piece of considerable thickness, and *bore a "cylindric interstice" between the case and cylinder, leaving them attached at one end!!!* In another part, he proposes to simplify the construction of the valves of the condensing engine, by connecting the upper and lower valves so as to work with one spindle or rod; the rod which connects them being tubular, answers as an eduction pipe to the upper end of the cylinder.

But the most notable invention here described is a rotative engine, which consists of two toothed wheels working into each other, and fitted into a double case, resembling two cylinders with a segment cut off each. *a b* (page 127) are the two axes upon which the two wheels D D are fixed. The teeth are supposed to be packed at the parts in contact with the exterior cylinder. The teeth which are in contact are so fitted as to prevent any escape in that direction. Steam being introduced at the pipe *z*, a rotative motion would be produced; but the construction would be so defective, and the friction so great, as totally to prevent its ever answering in practice. At the same time we ought to correct an erroneous opinion which many have formed respecting this machine, namely, that it would not move at all; it being thought, that as the surface of the teeth *e e* is as great as that of *f f*, consequently there would be as great a tendency to turn one way as another, and therefore no motion would be produced. But it will be seen that as the teeth *e e*, though individually of equal superficies with *f f*, overlap each other, the surface presented to the action of the steam is only equal to one tooth, therefore the effect of the steam (without calculating friction) would be one half of the real force.

The next invention we have to describe, will conclude our account of every modification of the steam engine, possessing genuine merit, with which our researches have enabled us to become acquainted, up to the end of the eighteenth century.

In the year 1800, Mr. Phineas Crowther, of Newcastle upon Tyne, obtained a patent for a method of dispensing with the beam of reciprocating engines, by placing the fly wheel immediately above the piston. *a* represents the cylinder; *b b* the parallel motion; and *c* the connecting rod. The principle will be seen by a slight inspection of the annexed drawing, without further explanation. Mr. Crowther constructed several good engines on this plan, which were found to succeed very well.

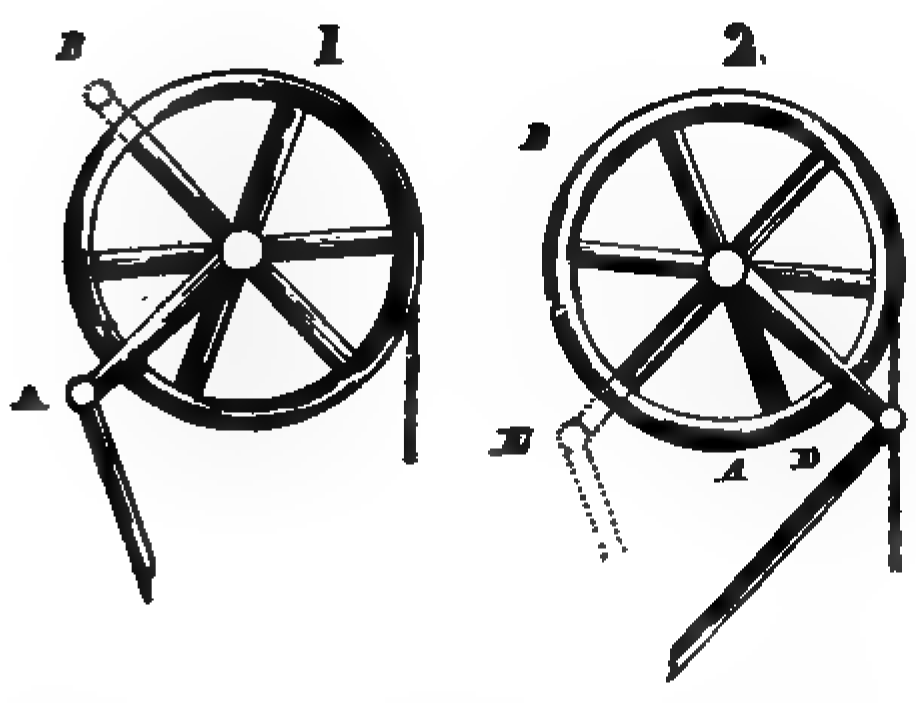
(*Crowther's Engine.* 1800.)

The Rev. Edward Cartwright obtained a patent for a Portable Engine, in 1801, of which the following is a description.

It consists, first, in so disposing the different parts of the steam engine, as that the boiler, the cylinder, the fly wheel, and all the moving parts of the engine, shall be

embraced by, comprehended within, or attached to a frame erected upon the boiler, and so connected together as to make one whole or perfect machine; so compact as to be easily portable; and requiring no further trouble and expense, after it is finished at the manufactory, than to place it upon the fire, when it will be immediately ready for the office for which it is intended; for this purpose, it will be most convenient to make the boiler oblong, and straight-sided, with a flat top, placing the cylinder within the boiler; a position which has, indeed, been already adopted by others, though for a different purpose. The frame extends lengthways on the sides of the boiler, and may project a little beyond that end of the boiler, where are fixed the air-pump and condenser. To the part of the frame so projecting, the air-pump and condenser may be attached or suspended. Across the frame is an axle, with a pulley upon it, round which goes a chain or strap, to the top of the piston rod. Upon this axis is a crank, from which goes a connecting rod to a lever, lying horizontally on the top of, or alongside the boiler. Besides the axis above-mentioned, there is another axis lying across, either immediately above or below, or on one side, of the former one. Upon this axis, which is the axis of the fly wheel, is a crank, from which goes a connecting rod to the same lever that was spoken of before.

Now it is evident, that when the pulley is put in motion by the action of the piston, the crank upon its axis will move the crank upon the axis of the fly wheel, as they are both connected to the same lever. If, therefore, the pulley be made to move in a direction from A to B, (see fig. 1.) and back again, by the action of the piston, and its counterweight; and if the crank upon its axis move in the same direction likewise, the crank upon the axis of the fly wheel will also do the same, unless it be made, as it must be, of such a determinate length as that, when it reaches the extremity of its motion, it can pass forwards; in that case, a rotatory motion is produced on the fly wheel. Again, if the crank upon the axis of the pulley be so disposed, as that when the pulley moves from A to B, or



(*Cartwright's Portable Engine.* 1801.)

through any space not exceeding a complete revolution, (see fig. 2.) the crank shall pass from C to E, through D, or in that direction, according to the space through which

any given point of the pulley passes the crank, will give two vibrations to the lever for one stroke of the engine, which will give two revolutions of the fly wheel in the same time. Again, if the diameter of the pulley be so reduced, as that the stroke of the engine shall make the pulley revolve once and a half round and back again, the crank will occasion the lever to vibrate three times for every stroke of the engine. Again, if the diameter of the pulley be so reduced as that it shall make two complete revolutions, and back again, for one stroke of the engine, in that case, the crank will give four vibrations to the lever for one stroke of the engine, and the fly wheel will revolve four times. By this invention the fly wheel may be made to run with any requisite velocity, without the intervention of any kind of wheel-work.

Secondly. For the purpose of lessening the waste of power, and regulating the velocity of the engine, instead of making the governor act upon the throttle valve, by causing it to give motion to a wedge, sliding at liberty backwards and forwards, under the weight which keeps the steam valve open. If in any particular case it should be thought convenient to have the fly wheel below, its axis must be placed underneath the lever, connecting it to the lever by a rod as before.

Thirdly. When a reciprocating motion is required horizontally, the connecting rod of either crank is extended as far below the lever as may be necessary, and at the bottom; that which is wanted to have a reciprocating motion hangs to it in a joint.

The air-pump, as well as any other pump that may be wanted, is worked by a lever, which receives action by the piston; and to such lever is applied the necessary counterweight.

If the engine be a double one, there must be a double chain or strap round the pulley, so that the piston may act upon the pulley, both in its descent and ascent. Or the action may be given to the axis of the crank by a rack and pinion.

A, the cylinder.

B, the boiler.

C, pulley put in motion by the piston and its counterweight.

D, the crank upon the axis of the pulley.

E, the connecting rod.

F, the lever.

G, the fly wheel.

H, the crank upon its axis.

I, rod connecting it to the lever F.*

This engine is portable and cheap, but, for ingenuity, we think it falls short of Mr. Cartwright's former scheme. Racks and pinions ought to be avoided, if possible; neither do chains deserve, in our opinion, greater commendation. Both these plans are inferior, in our judgment, to many engines in actual use at the date of this patent.

Mr. Matthew Murray's patent of 1801, contained more meritorious and useful schemes than his former patent, most of them being generally in use at the present day. We shall describe his valves, commonly called nozzles, nossels, or nozles.

o, in the following figure, is the pipe conveying steam from the boiler, and delivering it into the descending pipe *p*, which terminates in the valve *q*, opening to the lower part of the cylinder by the side opening marked as a shaded parallelogram, while the valve *r* opens a similar communication with the upper part of the cylinder; so that by the successive opening and shutting of *q* and *r*, steam is admitted above and below the piston: *s* is the lower end of the eduction pipe, joining on to the condenser, and this pipe opens first to the lower part of the cylinder by the valve *t*, and leads also by a perpendicular continuation of the same pipe *v*, to a valve *a*, by which a connexion is formed with the upper part of the cylinder. The two apertures into the cylinder, called nozzles, are therefore common both to the admission of steam, and formation of the vacuum, which is regulated simply by the working of the valves. For as the figure now stands,

* Specification of Patent, 1801.

(*Murray's Valves.* 1789.)

r is the only open valve in the steam pipe; consequently, steam would enter above the piston to depress it, while a vacuum would exist below it, on account of the valve *t*

being open to the condenser. As soon as the piston reaches the bottom of the cylinder, the valves *r* and *t* must be shut, and *u* and *q* opened; when the steam, being no longer able to get through *r*, would pass down the pipe *p*, and enter the lower part of the cylinder through *q*; meantime, *u* being open to the condenser by the pipe *v*, would cause the necessary vacuum above the piston to permit its ascent, which being completed, the valves must be again put into the position shewn in the figure, to produce its descent, and so on. It will be sufficient to state that these valves are operated upon, either by levers passing in a steam-tight manner through the side pipes, or that sometimes the spindles of the valves are made to act one through the other in stuffing, as in the present instance, when they are worked by external applications. It is likewise not unfrequent to connect a steam and condensing valve, when they are required to open and shut simultaneously, by an external rod. Motion is communicated to the valves in such engines as are without a fly-wheel, by a rod, or beam, attached to the engine beam, very near to the cylinder end of it, and called a plug-tree; this plug-tree is equipped with certain adjustable projections, called tappets, which strike the levers or handles of the valves, and thus open and shut them at the proper intervals, as they rise and fall with the beam.*

By this most ingenious contrivance no waste of steam arises, excepting in the small aperture between the valves; the friction is likewise much less than either slides, cocks, or indeed any other kind of valve—the only resistance to their motion being the pressure upon the upper side by the steam, when in their seats. Their cost, compared to that of the slide-valve, is much greater; but as they are not liable to wear, and work with great accuracy, the extra expense does not prevent their very general adoption for large engines.

At the same time Mr. Murray described a new air-pump, in which the air in the condenser was discharged

* Millington's Epitome.

(*Murray's Air-Pump.* 1801.)

from the air-pump without an effort to open the valves, or press through a body of water, and in which the air and water were discharged, separately, in different ways; this he effected by discharging the air alone by one bucket, and the water alone by another, or by an eduction pipe of twenty-eight feet in length. A represents the condenser; B the air-pump; C the air piston; D the air valve which is opened and shut by the working parts of the engine, and

has an elastic rod; E the valve for discharging the air· F the exhausting pipe, having a free communicatio betwixt the condenser and the top of the air-pump, wher , the valve D is open; G the eduction pipe; K a bucket fo lifting the water upwards, as in a common pump; L foot valve for preventing a return of the water during the descent of the bucket K; M the barrel of the pump for discharging water alone. This, together with an inspection of the preceding diagram, will serve to show the nature of his invention. The utility of the separate discharge of the air and water is unquestionable; but whether this will compensate for the increased expense and complexity, can only be ascertained in practice. Mr. Murray's scheme, however, has been again made the subject of a patent, a short time ago, by Mr. George Stephenson, of Newcastle.

In the same year (1801) Mr. Bramah obtained a patent for an improvement in the four-way cock, by causing it to make a continuous revolution, instead of a partial one (as used previously.) By this method, the wear was more regular, which rendered the cock durable, and it was likewise more certain and correct in its action.

Mr. John Nuncarrow's engine, for giving motion to a water-wheel, by a fall obtained by the power of steam, acts upon the same principle as those of Papin and Savery; but as his machine possesses many great advantages over theirs, we shall offer no apology for its insertion.

A is the receiver, which may be made either of wood or iron. B B B B B are wooden or cast-iron pipes, for conveying the water to the receiver, and thence to the penstock. C the penstock, or cistern; D the water wheel; E the boiler, which may be either iron or copper; F is the hot well for supplying the boiler with water; G G are two cisterns under the level of the water, in which the small bores B B and the condenser are contained. H H H is the surface of the water with which the steam engine and water wheel are supplied; *a a* is the steam pipe, through which the steam is conveyed from the boiler to he receiver; *b* the feeding pipe, for supplying the boiler

(*Nuncarrow's Engine.* 1801.)

with hot water; *c c c c c* the condensing apparatus; *d d* the pipe, which conveys the hot water from the condenser to the hot well; *e e e* valves for admitting and excluding the water; *f f* the injection pipe, and *g* the injection cock; *h* the condenser.

It does not appear necessary to say any thing here on the manner in which this machine performs its operations without manual assistance, as the method of opening the cocks, by which the steam is admitted into the receiver and condensed, will be readily conceived, being somewhat similar to the apparatus for working the valves of the common engine. But it will be necessary to remark, that the receiver, penstock, and all the pipes, must be previously filled, before any water can be delivered on the wheel; and when the steam in the boiler has acquired a sufficient strength, the valve as at *c* is open, and the steam immediately rushes from the boiler at E into the receiver A; the water descends through the tubes A and B, and ascends through the valve *e*, and the other pipe or tube B, into the penstock C. This part of the operation being performed, and the valve *c* shut, that at *a* is suddenly opened, through which the steam rushes down the condensing pipe *c*, and in its passage meets with a jet of cold water from the injection cock *g*, by which it is condensed; a vacuum being made by this means in the receiver, the water is driven up to fill it a second time, through the valves *e e*, by the pressure of the external air, when the steam valve at *c* is again opened, and the operation repeated for any length of time that the machine is required to work.

There are many advantages which a steam engine on this construction possesses, beyond any thing of the kind hitherto invented; a few of which the inventor thus enumerates:—

1st. It is subject to little or no friction.

2dly. It may be erected at a small expense, when compared with any other sort of steam engine.

3dly. It has every advantage which may be attributed to Boulton and Watt's engines, by condensing out of the

receiver, either in the penstock or at the level of the water.

4thly. Another very great advantage is, that the water in the upper part of the pipe adjoining the receiver acquires a heat by its being in frequent contact with the steam, very nearly equal to that of boiling water: hence the receiver is always kept uniformly hot, as in the case of Boulton and Watt's engines.

5thly. A very small stream of water is sufficient to supply this engine, even where there is no fall; for all the water raised by it is returned into the reservoir H H H. From the foregoing reasons it would seem that no kind of steam engine is better adapted to give rotary motion to machinery of every kind than this. Its form is simple, and the materials of which it is composed are cheap; the power is more than equal to any other machine of the kind, because there is no deduction to be made for friction, except on account of turning the cocks, which is but trifling.

But it should be observed on the other hand, that one of the properties of this machine, enumerated by the inventor as an advantage, would be found rather a defect than otherwise; we allude to the water in the upper part of the pipe being heated by the steam. For though less steam would be lost by condensation, yet it should be remembered that it is impossible to form a vacuum on the surface of boiling water. The only way, therefore, that the water could be raised up the column B, would be by the condensation in C being more rapid than the steam could be generated from the boiling water in B. But we apprehend steam would be generated thus almost as quickly as it could be condensed, and therefore the operation of filling B would prove very slow. The addition of a non-conducting float might probably, in part, obviate this objection.

Mr. Oliver Evans, of America, whose claim to the invention of the Steam Boat will be noticed in its proper place, succeeded in constructing several extremely simple

and powerful steam engines; the general principle of which will be sufficiently explained by the subjoined description.

In the annexed figure, A is the boiler, B the working cylinder, C the lever beam, D the fly wheel, E the cistern or condenser, F the cold-water pump, G the supply pump, H the fire-place, I the chimney flue, K the safety valve, which may be loaded with from 100 to 150 lbs. to the inch area; it will never need more, and it must never be fastened down.

The boiler being filled with pure water (rain or distilled) as high as the dotted line, and the fire applied, the smoke enters the centre flue, which passes through the centre of the water to ascend the flue I, and thus acts on a large surface.

When the steam lifts the safety valve, it is let into the cylinder by opening the throttle valve, and drives the piston up and down, which, by the rod 1, gives motion to the fly wheel; and the wheel 2 gives motion to a shaft, passing through the supports of the cylinder to turn the spindle of the rotary-valves, 3, 8, which lets the steam both into and out of the cylinder, at the proper time.

The steam, escaping by the pipe 4, curved backwards and forwards in a zigzag form, and immersed in the water in the cistern E, (which is supplied by the cold-water pump F,) is condensed; and the distilled water formed thereby descends, by the pipe 5, into the supply pump G, and is forced into the boiler again by the pipe 6.

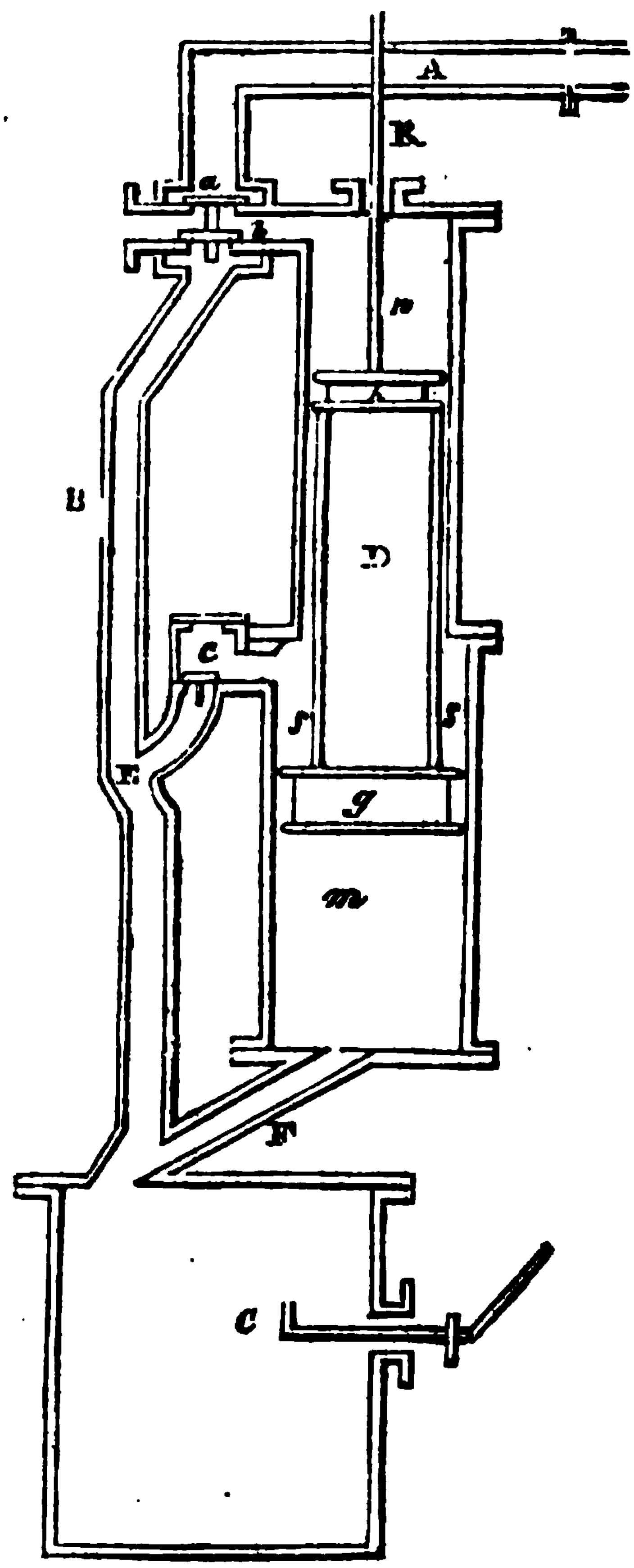
But as boiling disengages air from the water, so the shifting-valve, 7, is necessary. This valve lifts at every puff of the steam, and a small quantity escapes; it then shuts, and a vacuum is instantly formed, as the crank passes the dead points.

The small waste of water may be replaced by condensing water in the cistern E, and causing it to run down the pipe G, through a hole in the key of a stop-cock, one-32d part of an inch in diameter; a small hole, indeed, to supply a boiler of a steam engine, of twenty horses' power.

(*Oliver Evans's High-Pressure Engine.* 1786.)

In 1801, Messrs. John and James Robertson, of Glasgow, obtained a patent for an improved steam-engine, the form of which differs little in construction from many other engines, except that, in place of one working cylinder, in these there are two; in this, the lesser cylinder (*n*) is placed on the top of the larger (*m*), and made fast to it. To each cylinder there is a piston fitted, which are connected together by a cylinder D: or this cylinder is so made as to have the pistons in one piece with it. This cylinder is made so that it may nearly fill the small cylinder *n*; that is, that it may work up and down so that the external surface of the one may not rub on the internal surface of the other. The steam and conducting pipes, with the valves, are explained in the accompanying diagram and following description of the operation of the engine:—

"Let the working handles, with the valves, be placed in such a manner, that steam from the boiler may have free access through the pipes and cylinders into the condensing vessel, to free the whole of the air, as in the usual manner. When this is done, the engine is set to work by the valves *b* and *c* being shut, and by that of *a* left open, and water let into the condensing vessel C, when a vacuum takes place in it by means of the condensation of the steam, and also in the under part of the large cylinder *m*, below its piston (there being a communication from



(*John & Jas. Robertson's Engine.* 1801)

condensing vessel by the pipe F); at the same time the steam from the boiler has free access through the pipe A, and valve *a* into the small cylinder *n*, above its piston *k*, and exerts its force upon it, and presses it downwards with as much force as in the usual manner. But as it is found, from experience, that a considerable quantity escapes past the piston: this piston is in part detained by the secondary piston *g*, and exerts its force on that part or annular section *s s* that is contained betwixt the cylinders *m* and D, and assists in forcing the whole downwards; while, at the same time, the steam which is lodged in this annular space *s s*, and around the cylinder D, prevents so great a quantity from escaping past the first piston, as would otherwise be the case where there is no secondary piston, and the vacuum is much more complete below the first piston, consequently there is a greater power produced from a smaller quantity of steam than with a single piston. During the time of the piston's descent, the steam valve *a* is shut, and the elasticity of the steam within the cylinders carries the pistons forward to near the bottom of these cylinders, when the valves *b* and *c* are opened by the handles and plug-work admitting the steam to pass from the upper sides of both pistons through the pipes B and E to the condensing vessel C, while the counter-weight at the other end of the beam, or this connected with a fly wheel raises the pistons again, when the valves *b* and *c* are shut, and that of *a* opened by the plug-work, when the engine makes another stroke as before. The piston rod R joins the working beam in any of the usual modes, and in other respects the engine is much the same as in common practice."

The same specification describes a most ingenious method of constructing the furnace, by which the smoke was partially consumed, instead of being discharged as hitherto through the chimney. Messrs. Robertson have the credit of being the first who succeeded in this project. After the adoption of this plan, several manufacturers, for not using the improvement, had their works indicted as nuisances, as the smoke incommoded many neighbourhoods so much, that some manufactories were stopped on account of it.

The invention, in principle, consists in supplying the burning fuel more fully with air, having this fuel more in a body together, and a less quantity in combustion, at the same time, than what usually takes place in other furnaces, which are applied to the same uses; in supplying the fuel with a portion of fresh air, admitted from an opening made for that purpose, and directed in such a manner as it may come in contact with the smoke, from the kindling coal and great heat of the furnace together; and the fuel being more fully supplied with air, and consequently a greater degree of heat taking place, and the smoke and fresh air uniting in the great heat, the smoke is inflamed, and rendered useful in adding to the heat of the furnace; besides, this portion of fresh air is so conducted as to act partly on the kindling or kindled fuel, and raising it to a greater degree of heat after it has served its purpose, by uniting with and inflaming the smoke; and therefore is employed, in some measure, usefully, even after the coal has ceased to smoke: secondly, to the above may be added, the frame of the furnace, which is so constructed that the full-kindled fuel is kept backward in the furnace, while the fresh coal lies before, and is more gradually kindled than if introduced farther among the full-kindled fuel, while the heat of the furnace is little injured or damped by the introduction of fresh coal, as is more fully described afterwards.

The coal is admitted into the furnace by a hopper, feeder, or mouth-piece A, made of cast iron, but which may be made of other materials, and inclined to the horizon; so that the coal in it may, in some measure, fall into the fire-place above the bars, as the fuel is consumed; in the upper part of this hopper, feeder, or mouth-piece, is a plate *a*, placed at a small distance, or from about three-eighths to three-fourths of an inch from the upper side of the hopper, betwixt which plate and the upper plate, or side of the hopper, a stream of air rushes downward on the fire, at an angle of 45 degrees to the horizon, which stream of air assists in consuming the smoke, as before mentioned, and more fully described hereafter. B is a section of the bars, which are, in general, a little inclined to the horizon, as in the figure, in order that the fuel may more easily fall, or be pushed backwards in the furnace; at *c* is an opening above the bars, and below the lower end of the hopper, which is in general fitted with a grated door or doors, which open for the more convenient cleansing of the furnace; and the grated form of the doors is also designed for admitting air into the fuel, as well as at the bars, consequently the air is more concentrated in the middle of the burning fuel, and produces a greater heat than if admitted only betwixt the bars; this grated form of the doors is very convenient for the admission of a poker or instrument for pushing backward the kindled fuel, while the fresh coal, or that which is not so well kindled, falls to supply its place. In some modifications of these furnaces, the opening below the lower end of the hopper, and above the fore-end of the bars, is left without doors at all; at this opening it is convenient, when the fire is mended, to push the coal from the foreside backward, as mentioned above, or it may be pushed backward with a hooked poker, P, by applying the hooked part of it through the furnace bars below; by either of which means the kindled coals are put backwards, while the fresh coal, or that which is not so well kindled, falls down to supply their place; that is, the coals in the situation *c*, are pushed towards *d*, while those in the situation *f* fall down to supply the place of

those which were driven from *c* towards *d*; by such means the strength or heat of the fire is not much damped by the introduction of fresh coal, and the coals which have fallen from *f* towards *c* are not so rapidly kindled, as if introduced above the burning fuel; at the same time the smoke, which arises from these newly-introduced coals, passes partly through the full kindled coal and partly over, and in contact with the great heat of the burning fuel, and, meeting at the same time with the current of fresh air coming downwards, and tending also to drive the smoke still nearer to the bright kindled fuel, does, in general, completely inflame the smoke, and render it useful in adding to the heat of the furnace.

Another end obtained by the stream of fresh air, is to keep in some measure the great heat of the furnace from acting so violently on that part of the hopper which is nearest it, and mostly exposed to its heat, and liable to be damaged thereby, which it does by the continual current of fresh cool air that is in contact with those parts. The construction of the furnace may be much varied, but the chief improvements are, that the fuel in combustion is supplied with air by the foreside as well as by the bars; the hopper is placed in such a situation that the kindled or unkindled coal may in part fall to the foreside of the furnace above the bars, as the other fuel is pushed backward in the furnace, and the admission of fresh air to pass over the burning fuel by means of a definite space or spaces, opening or openings, made for that purpose; so that this stream, current, or currents of air, partly come in contact with the burning fuel itself, forcing also the smoke into more immediate union with the burning fuel and great heat of the furnace. The success of the furnace depends also in a considerable degree upon what is called the draught of the furnace; that is, the chimney and flues are so constructed, that a sufficient current of air may pass through the fire to bring it to a proper degree of heat; also, that the current of fresh air may have such force as to come pretty much in contact with the burning fuel, and to convey the smoke along with it through the hottest of

the flame: if this be not the case, the smoke will not be so completely consumed in these furnaces. The hopper is allowed to be kept as full of coals as possible, and either wholly or in part small coal, so as to prevent air as much as possible getting in by that passage; this must be attended to, when the furnace is in its ordinary working state: yet sometimes it is necessary to keep this opening of the hopper either wholly or in part open, when there is little heat wanted.

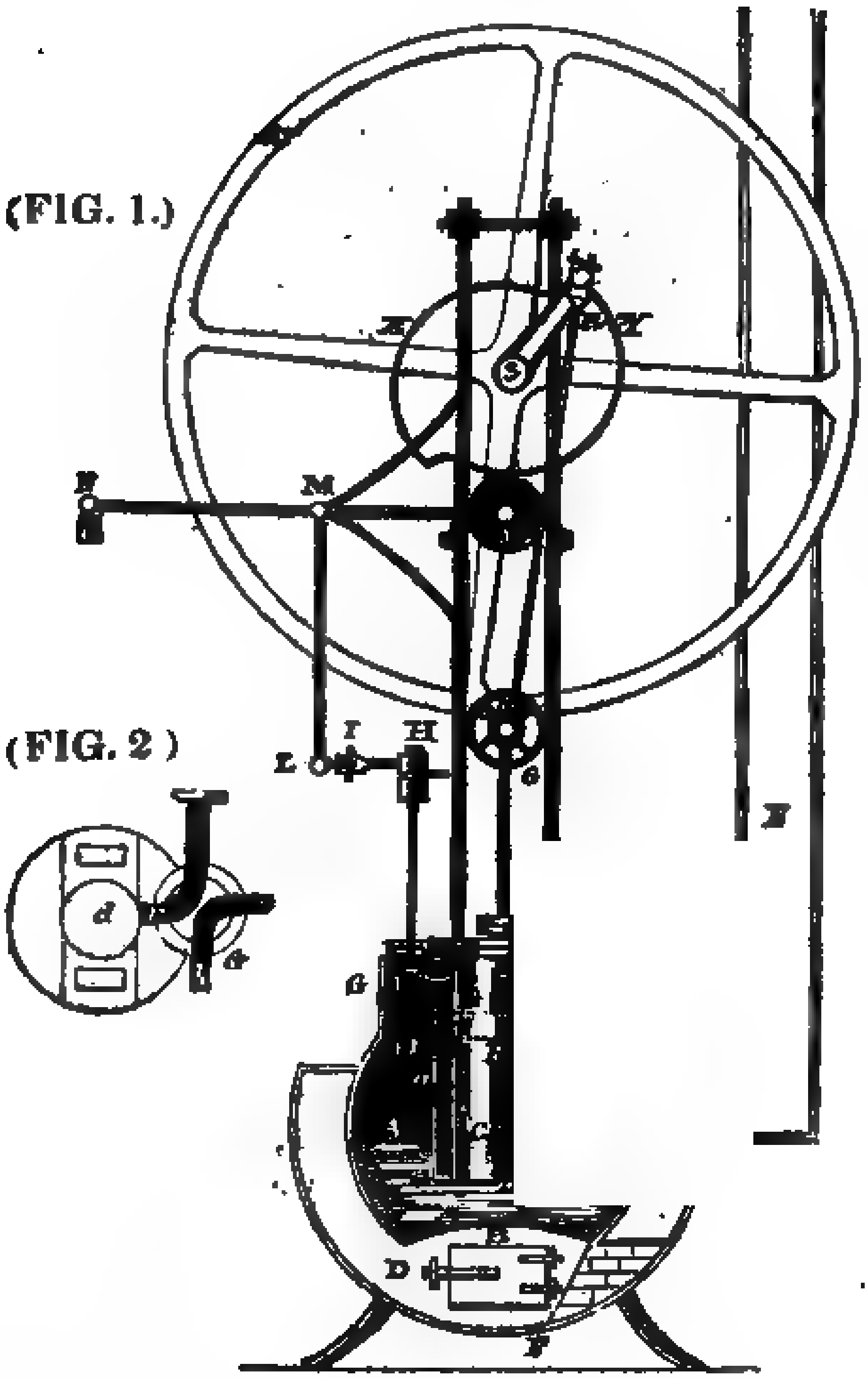
The utility of this scheme was sufficiently proved by the very general adoption which followed its publication. The combustion of smoke is now established as not only practicable, but economical,—it being a fact, that all the smoke discharged from a chimney is but so much good fuel, which wants only the proper application of air to render it useful. It is equally true, that the flame which is frequently at the top of furnace chimneys has no existence but at the top; while ascending the flue, it is merely dense smoke, consisting of azote of the atmospheric air, decomposed in passing through the fire; of hydrogen, coal-tar, and carbonaceous matter, of such a high temperature that it only wants oxygen to make it inflame spontaneously; this it obtains from the atmospheric air, into which it ascends, and then presents such appearances as would make a hasty observer adopt the opinion, that the flame had ascended as flame from the fuel in the furnace, which is by no means the case.

Messrs. Trevithick and Vivian's High-Pressure Engine (patented in 1802) has been found the most compact, simple, and effective engine, perhaps, ever known. In an early part of this work reasons are given for the superiority of high-pressure over condensing engines; and we shall only now say, that Messrs. Trevithick and Vivian's engine has, of all others on this principle, obtained the highest reputation.

"A, (fig. 1.) represents the boiler, made of a round figure, to bear the expansive action of strong steam. The boiler is fixed in a case, D, luted inside with fire clay, the lower part of which constitutes the fire-place, B, and the

(FIG. 1.)

(FIG. 2.)



(*Trevithick and Vivian's High-Pressure Engine* 1802.)

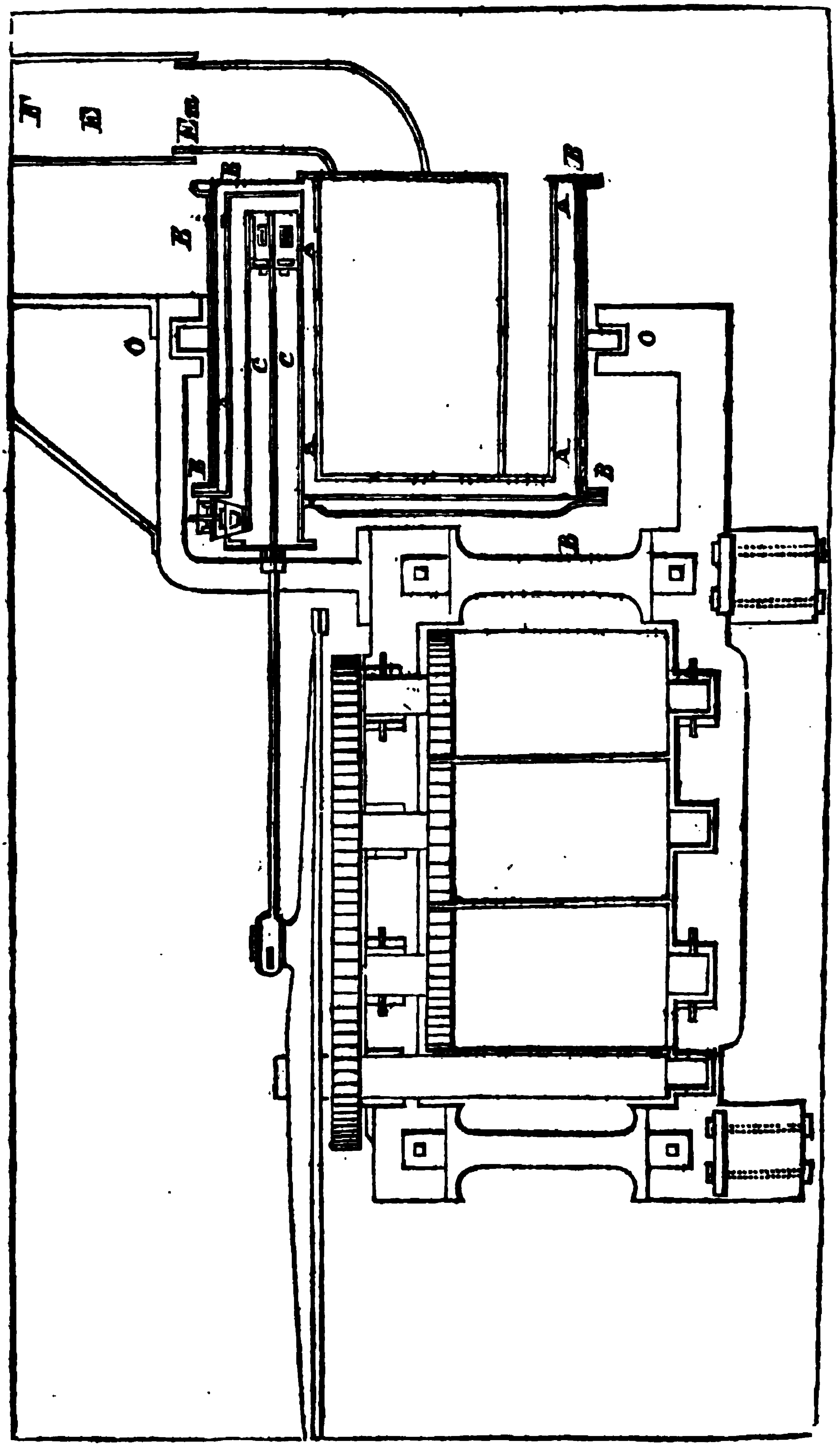
upper cavity affords a space round the boiler, in which the flame or heated vapour circulates till it comes to the chimney, E. The case, D, and the chimney are fixed upon a platform, F, the case being supported upon four legs; C represents the cylinder, inclosed for the most part in the boiler, having its nozzle, steam-pipe, and bottom, cast all in one piece, in order to resist the strong steam, and with the sockets in which the iron uprights of the external

frame are firmly fixed. G represents a cock for conducting the steam, as may be more clearly seen by observing fig. 2, which is a plan of the top of the cylinder. *b*, Figs. 1 and 2, represent the passage from the boiler to the cock, G; this pasage has a throttle valve, or shut, adjustable by a handle, so as to wiredraw the steam, and suffer the supply to be quicker or slower. The position of the cock is such, that the communication from the boiler, through *b*, by a channel in the cock, is made good to *d*, which denotes the upper space of the cylinder above the piston, at the same time that the steam pipe, *a*, (more fully represented in Fig. 1.) is made to afford a passage from the lower space in the cylinder beneath the piston to the channel, C, through which the steam may escape into the outer air, or be directed or applied to heating fluids, or other useful purposes. It will be obvious that, if the cock be turned one quarter of a turn in either direction, it will make a communication from the boiler passage, *b*, to the lower part of the cylinder, by or through *a*, at the same time that the passage *r*, from the upper part of the cylinder, will communicate with C, the passage for conveying off the steam. P Q is a piston rod moving between guides, and driving the crank, R S, by means of the rod, Q R, the axis of which crank carries the fly, T, and is the first mover to be applied to drive the machinery at S. X Y is a double snail, which in its rotation presses down the small wheel O, and raises the weight, N, by a motion in the joint, M, of the lever, O N, from which downwards proceeds an arm, M L, and consequently the extremity, L, is at the same time urged outwards. This action draws the horizontal bar, L I, and carries the lever handle, H I, which moves upon the axis of the cock, G, through one-fourth of a circle. It must be understood that H I is fore-shortened, (the extremity, I, being more remote from the observer than the extremity, H,) and also there is a clack or ratchet wheel on the part, H, which gathers up during the time that L is passing outwards, and does not then move the cock, G, but that, when the part X, of the snail opposite O, that is to say, when the piston is about the top of its

stroke, then the wheel, O, suddenly falls into the concavity of the snail; and the extremity of L, by its return, at once pushes I H through the quarter circle, carries with it the cock, G, and turns the steam upon the top of the piston, and also affords a passage for the steam to escape from beneath the piston. Every stroke, whether up or down, produces this effect by the half turn of the snail, and reverses the steam ways, as before described; or the cock may be turned by various well-known methods, such as the plug with pins or clamps striking on a lever in the usual way, and the effect will be the same, whether the quarter turns be made backward or forward, or by a direct circular motion, as is produced by the machinery here represented; but the wear of the cock will be more uniform and regular, if the turns be all made in the same way.'

The same specification likewise describes a very simple and ingenious method of giving motion to the fly wheel, by making the piston rod of an inflexible bar, and connecting it at once with the crank. The cylinder and boiler are allowed to vibrate on pivots, and thereby follow the revolving of the crank. The drawing here given represents also the outline of a machine for rolling sugar canes, thereby showing at once the connexion of the engine with the machinery of the mill.

"In the subjoined diagram, the working cylinder, C, with its piston, steam pipe, nozzle and cock, are inserted in the boiler, as here delineated. The piston rod drives the fly, upon the arbor of which is fixed a small wheel which drives a great wheel upon the axis; the guides are rendered unnecessary in this application of the steam engine, because the piston rod is capable, by a horizontal vibratory motion of the whole engine upon its pivots, O, to adapt itself to all the required positions; and while the lower portions of the chimney partake of this vibratory motion, the upper tube, E F, is enabled to follow it by its play upon the two centres or pivots in the ring above. In such cases, or constructions, as may render it more desirable to fix the boiler with its chimney and other apparatus, and to place the cylinder out of the boiler, the cylinder



(Plan of Trevithick & Vivian's Vibratory Engine, and its application to a Sugar-cane Mill. 1802.)

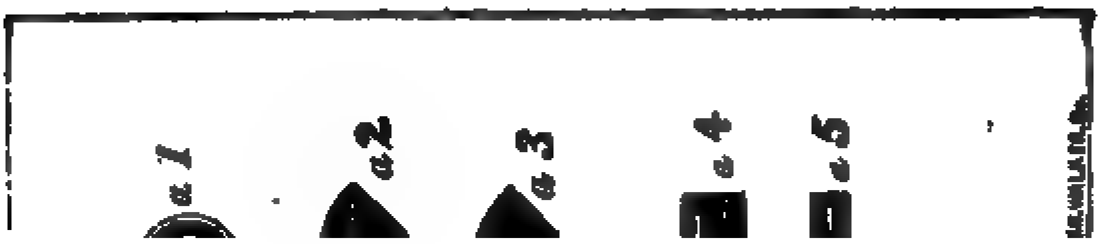
itself may be suspended for the same purpose upon trunnions or pivots in the same manner, and one or both may be perforated, so as to admit the introduction and escape of the steam, or its condensation. And in such cases, where it may be found necessary to allow of no vibratory motion of the boiler or cylinder, the same may be fixed, and guides be used. The manner in which the cock is turned is not represented in the two drawings, but every competent workman will, without difficulty, understand how the stroke of pins duly placed in the circumference of the fly, and made to act upon a cross fixed on the axis of the cock, or otherwise, will produce the motion. The steam which escapes in this engine is made to circulate in the case round the boiler, where it prevents the external atmosphere from affecting the temperature of the included water, and affords by its partial condensation a supply for the boiler itself, and is or may be afterwards directed to useful purposes."

This latter plan, namely, the vibrating cylinder, looks well in theory, but we fear in practice it would be found very imperfect. Reciprocation, as we have shown, is a great destroyer of power, and here the whole engine, boiler, water, cylinder, fire-grate, and all the apparatus, are constantly moving backwards and forwards, and all this, too, merely to *dispense with the guide wheel and connecting rod.*

Mr. Matthew Murray, of Leeds, obtained a patent for a Portable Engine, in 1802, which displays much novelty and ingenuity. The annexed figs. 1. and 2. represent front and side views of the combination of parts of this engine.

"A the steam cylinder; B the piston rod; C C, connecting-rods, for conneeting the piston rod to the pin in the wheel D; E a wheel, fixed to the side of the cistern I, with the teeth inwards, to admit the teeth of the wheel, D, for the purpose of giving a parallel direction to the rods, C C; F a plain wheel, upon the fly-wheel shaft, G; the wheel, F, is furnished with a double conical centre, for the wheel, D, to run upon; I is a cistern or frame of plates, on and in which the whole combination of materials constituting this engine is fixed; K K two wheels,

MURRAY'S PORTABLE ENGINE.



(*Matthew Murray's Portable Engine.* 1802.)

one upon the fly-wheel shaft, G, the other upon the crank shaft, L; these wheels and crank are for the purpose o working the lever, R, in fig. 2, which lever gives immediate motion to the air-pump, P, and the cold and hot water pump; T is an iron bar for supporting the shaft; M is a slide valve for opening and shutting the communication of the steam pipes, marked N N N, and is described in figs. 3, 4, 5, 6, and 7; a motion for the slide valve is taken from the crank shaft, L, by levers, or otherwise, as the nature of the valve may require. The parts so combined form a perfect engine, without requiring any fixture of wood, or any other kind of framing than the ground it stands upon, which is transferable without being taken in pieces, the motion of the fly-wheel shaft giving circular power to any process or manufactory requiring circular motion, or irrigating land, or for the various purposes of agriculture. Figs. 3, 4, 5, 6, and 7, represent various forms of the new slide-valve, in its application to the steam-engine; the principle of which consists in moving in a circle, part of a circle or straight line, by means of flat surfaces or faces (or nearly so) sliding or moving upon each other, for the purpose of uniting the necessary apertures in the steam pipes or cylinders. Fig. 3. is a view of a circular flat sliding valve; the dotted lines show the avenues to the steam pipes. *a* 1, is a figure representing the upper or moveable part of the slide valve, fig. 3. where the conducting or uniting cells are formed: there is a circular spring for compressing *a* 1 to the face of the slide valve in fig. 3, so as to render them perfectly steam and air tight, which perfection they will naturally acquire by constantly rubbing upon each other. Figs. 4, 5, 6, and 7, show four varieties of the slide valve, for working double or single powers. *a* 2, *a* 3, *a* 4, and *a* 5, contain the cells for conducting to the different apertures or steam ways. Any further description is unnecessary, as the drawings will convey to any one the principles of these inventions."*

* Specification of Patent.

This ingenious apparatus, though possessing much merit, infringed, it appears, on the patent right of Messrs. Boulton and Watt, and the patent was, therefore, repealed in 1803. An engine on this plan has been at work many years at St. Peter's Quay, on the river Tyne, and is found to answer uncommonly well.

Mr. Woolf's very excellent and ingenious boiler (patented in 1803) comes next under our notice. The great utility of this apparatus induces us to give the specification, together with Mr. Woolf's own remarks, in full.

"Mr. Woolf's improved apparatus consists, first, of two or more cylindrical vessels properly connected together, and so disposed as to constitute a strong and fit receptacle for water, or any other fluid intended to be converted into steam, whether at the usual heats, or at temperatures and under pressures uncommonly high; and also to present an extensive portion of convex surface to the current of flame or heated air or vapour from a fire. Secondly, of other cylindrical receptacles placed above these cylinders, and properly connected with them, for the purpose of containing water and steam, and for the reception. transmission, and useful application of the steam generated from the heated water, or other fluid. And, thirdly, of a furnace so adapted to the cylindrical parts just mentioned, as to cause the greater part of the surface of all and each of them, or as much of the said surface as may be convenient or desirable, to receive the direct action of the fire, or heated air and vapour.

"One of his boilers, in its most simple form, consists of eight tubes, made of cast-iron, or any other fit metal, which are each connected with a cylinder placed above them. The fuel rests on the bars, and the flame, heated air, and vapour, being reverberated from the part above the two first smaller cylinders, goes under the third, over the fourth, under the fifth, over the sixth, under the seventh, and partly over and partly under the eighth small cylindric tube. When it has reached the end of the furnace, it is carried to the other side of the wall, built under and in the direction of the main cylinder and then returns under the

(Woolf's Patent Steam Engine Boiler. 1803.)

seventh smaller cylinder, over the sixth, under the fifth, over the fourth, under the third, over the second, and partly over, and partly under the first; when it passes into the chimney. The wall before mentioned, which divides the furnace longitudinally, answers the double purpose of lengthening the course which the flame and heated air have to traverse, giving off heat to the boiler in their passage, and of securing from being destroyed by the fire the flanges or other joinings employed to unite the smaller tubes to the main cylinder. The ends of the smaller cylindric tubes rest on the brick-work which forms the sides of the furnace, and one end of each of them is furnished with a cover, secured in its place by screws, or any other adequate means, but which can be taken off at pleasure, to allow the tubes to be freed from time to time from any incrustation or sediment which may be deposited in them. To any convenient part of the main cylinder a tube is affixed, to convey the steam to the steam engine, or to any vessel intended to be heated by means of steam.

"When very high temperatures are not to be employed, the kind of boiler just described is found to answer very well; but where the utmost force of the fire is desirable, Mr. Woolf, for a reason which shall be afterwards mentioned, combines the parts in a manner somewhat different, though the same in principle.

"In fig. 2, A is the main cylinder crossing the smaller cylinders *a a a*, half way between their middles and ends, but not joined to any of them, excepting the middle one at the points at which it crosses them. It is put in this place that it may come over that part of the furnace, S S S, fig. 1, through which the flame first passes, and receive its direct action, which it does over nearly a half of its surface, as may be seen by looking at the vertical section, A S S, fig. 1. The smaller cylinders have a communication with the main cylinder in the following manner:—Three cylinders, C C C, are placed parallel to the main cylinder, A, over the part of the furnace by which the flame returns, in such a manner that each of the cylinders, C C C, takes in three of the smaller cylinders, *a a a*, being united to

and connected with them. The cylinders, C C C, have a direct communication with the main cylinder, A, by the pipes or tubes, P P P, as may be better seen by the cross vertical section, fig. 1. The three tubes C C C, are preferred to one long tube, to prevent any derangement taking place in the furnace or in the tubes, by the expansion or contraction occasioned by changes of temperature, which is more considerable in one tube of the whole length of the furnace, than when divided into three portions; and it is for the same reason that the tube A is not made to communicate directly with the smaller tubes, *a a a*, but mediately, by means of the tubes marked C and P.—N. B. The two outermost of the tubes marked P, instead of going parallel to the middle tube, P, may be both inclined towards it, so as to join the cylinder A near the middle; or any other direction may be given to them, to prevent derangement by expansion.

"The tubes C and *a* are kept from separating by bolts from the inside of *a* passing through the top of C, where they are secured by nuts screwed on to them, (see fig. 3.); and these parts of C are so contrived, that by taking off any of the nuts a cover may be removed, and a hole presented large enough to admit a man's hand into C, to clean it out.

"Fig. 3. is a longitudinal vertical section of the furnace, through the centre, showing the course which the flame and heated air are forced to take. The first three small cylinders are completely surrounded with flame, being directly over the fire: the flame is stopped by the brick-work, W, over the fifth, and forced to pass under it, and then over the sixth, where it again meets with an interruption, which forces it to go under the seventh, and over the eight; it then turns round the end of the longitudinal wall which divides the furnace, and passes over the eighth smaller cylinder, under the seventh, and so on, alternately, over and under the other tubes, till it reaches the chimney. The wall that divides the furnace may be seen in fig. 2.

"To secure a free communication between the different parts of the boiler, the three tubes of the middle cylinder,

C. are connected with those of the two exterior C's, by two pipes, *o o*. The other ends of the tubes, *a a a*, are each fitted with a cover properly secured and bolted, but which can be taken off occasionally, to clean out the boiler.

"In working with such boilers, the water carried off by evaporation is replaced by water forced in by the usual means; and the steam generated is carried to the place intended by means of tubes connected with the upper part of the cylinder A.

"It may not be improper," says Mr. Woolf, "to call the attention of those who may hereafter wish to construct such apparatus, to one circumstance; namely, that in every case the tubes composing the boiler should be so combined and arranged, and the furnace so constructed, as to make the fire, the flame, and the heated air, to act around, over, and among the tubes, embracing the largest possible quantity of their surface. It must be obvious to any one that the tubes may be made of any kind of metal; but I prefer cast-iron as the most convenient. The size of the tubes may be varied: but, in every case, care should be taken not to make their diameter too great; and it must be remembered that the larger the diameter of any single tube in such a boiler, the stronger it must be made in proportion, to enable it to bear the same expansive force as the smaller cylinders. It is not essential, however, to my invention that the tubes should be of different sizes; but I prefer that the upper cylinders, especially the one which I call the main cylinder, should be larger than the lower ones, it being the reservoir, as it were, into which the lower ones send the steam, to be thence conveyed away by the steam pipe or pipes. The following general direction may be given respecting the quantity of water to be kept in a boiler in my construction: it ought always to fill not only the lower tubes, but the main cylinder, A, and the cylinder, C, to about half their diameter, that is, as high as the fire is allowed to reach, and in no case ought it to be allowed to get so low as not to keep full the necks or branches which join the smaller cylinders, marked with the letter *a*, to the cylinders A or C; for the fire is only beneficially

employed when applied, through the medium of the interposed metal, to water, to convert it into steam: that is, the purpose of my boiler would, in some measure, be defeated, if any of the parts of the tubes exposed to the direct action of the fire, should present in their interior a surface of steam instead of water, to receive the transmitted heat which must, more or less, be the case, if the lower tubes, and even a part of the upper, be not kept filled with the liquid.

"As to the construction of the furnaces, though that must be obvious from the drawings, it may not be improper here to remark, that they should always be so built as to give a long and waving course to the flame and heated air, or vapour, forcing them the more effectually to strike against the sides of the tubes which compose the boiler, and so to give out a large portion of their heat, before they reach the chimney: unless this be attended to, there will be a much greater waste of fuel than necessary; and the heat, communicated to the contents of the boiler, will be less from a given quantity of fuel.

"My invention is not only applicable to all the uses to which the boilers in common use are generally applied, but to all of them with much better effect than the latter; and can, besides, be applied to purposes in which boilers, constructed as they have hitherto been, would be of little or no use. The working of all kinds of steam engines is one important application of my invention; for the steam may be raised, in a boiler constructed in the manner before described, to such a temperature, and consequently to such an expansive force, as to work an engine even without condensing the steam, by simply allowing it to escape into the atmosphere after it has done its office, as proposed by Mr. James Watt, in the specification of his patent, dated January 5, 1769, whence, he says, engines may be worked by the force of steam only, by discharging the steam into the open air. In all cases where it is desirable to heat or boil water, or other fluids and substances, without the direct application of fire to the vessel or vessels containing them, which in such cases become secondary boilers, the

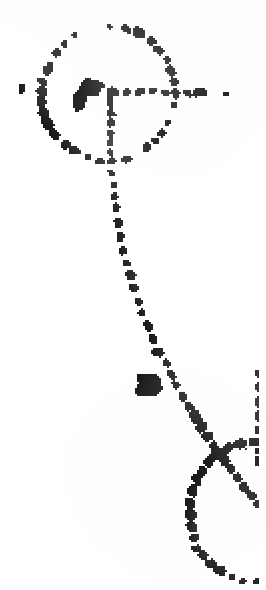
use of my apparatus will produce superior to any obtained by any other means, no more being necessary than to make the vessels, or secondary boiler, containing the water or other fluids, and the substances immersed or dissolved in, or blended or mixed with the water or other fluids, to communicate, by means of a tube or tubes, with the prime boiler, constructed in the manner before described. In such cases as in making extracts of every kind, for the various purposes of arts and manufactures, and for the simple boiling of water or watery fluids, the steam should go directly into the vessel or secondary boiler, whose contents are to be heated or boiled; and the orifice or orifices of the pipe or pipes through which the steam is conveyed, should go to a considerable depth in the fluid, that the steam may be better able to give off its heat, and be condensed before it can reach the surface; and in every such case an allowance should be made for the increase which will be made to the quantity of liquid in the vessel to be heated, by the quantity of steam which will be condensed in the same before the process be ended. The vessels into which the steam is thrown may be either open or close, as the nature of circumstances may require: but where extracts are to be made from vegetable or other matters, from which extracts are or may be made, as from hops, bark, drugs, and dry stuffs, for brewing, tanning, dyeing, and other processes, the materials will be much more completely exhausted of all their valuable parts; and in many instances they will be completely dissolved by employing close vessels, which, in that case, must be made very strong, a thing not difficult to be accomplished, when it is recollected that they may be at a distance from, and consequently out of the power of being deranged by the fire; and that they may be surrounded with, and, as it were, buried in massy stone or brick work, in addition to other and obvious means of securing them. My apparatus so employed, becomes, in fact, an improved Papin's digester on a large scale. I do not wish to be understood as claiming the merit of having been the first who applied steam in the manner just described to boil water and other

fluids, but merely as pointing out an important use to which my apparatus is applicable, and in which the effect obtained will be much greater than by any other means.

"Another important use to which my invention can be applied with better effect than the means now in use, is that of distillation on the large scale; and that by either sending the steam directly into and among the contents of the still or alembic, or by enclosing the still in another vessel, and making the steam of a high temperature to circulate in and to occupy the space between the exterior surface of the still, and the interior surface of the containing vessel. In either case, all danger of burning or singeing the materials operated upon is done away, and a much more pleasant and pure spirit will be obtained than by the methods now in common use. I need not stop here to show the reason why, even in the case of throwing the steam directly into the still, the spirituous part will be the first to rise and pass over into the receiver.

"I might mention many other useful applications that may be made of my invention; but I shall only state one more, namely, to the drying of gunpowder, and lessening the danger of explosions in the manufacture of that article. By means of my invention any desired temperature, necessary for that purpose, may be produced where the powder is to be dried, without the necessity of having fire in, or so near the place, as to endanger its safety; for by employing steam only, conveyed through pipes, and properly applied and directed, without allowing any of it to escape into the room or apartment where the powder is, any competent workman can produce a heat equal to that found necessary for drying gunpowder, or much higher, if required. Nor is the lessening of the danger of explosions the only advantage which this way of drying gunpowder holds out; it presents another, and an essential one for the goodness of the article; the heat can be completely regulated, so as to prevent, or at least lessen, the partial decomposition of the powder by the sublimation of the sulphur, which is found to take place by the methods at present in use."

We have had frequent opportunities of inspecting this excellent apparatus, and can, therefore, speak with confidence of its utility. One engine of Mr. Woolf's is now used by Mr. Smart, of Lambeth Marsh, with such a boiler to drive a saw mill, and is principally kept going by employing the saw-dust from the mill as fuel. Two safety valves or steam regulators are generally used, the plan of which is ingenious.



(*Woolf's Safety Valve.* 1803.)

A in the preceding figure is a part of the main cylinder of one of Mr. Woolf's boilers; B B the neck or outlet for the steam, surmounted by the steam box C, which is joined to the neck B B by the flanges *a a*. The top or cover of the steam box C, marked with the letter D, which is well secured in its place, has a hole through it for the rod of the valve, so contrived as to answer the purpose of a stuffing box, to make the rod work up and down steam-tight, the stuffing being kept in its place by the usual means, as shewn in the section. By means of a pin or nail

b, and the two vertical pieces *e e*, the piston rod is made fast to *m*, which is a cover of and joined to the hollow cylinder *n n*. The cover *m* fits steam-tight into the collar *o o*, which is made fast to the flanges *a a*. The cylinder *n n* is open at the bottom, having a free communication with the main cylinder A, and has three vertical slits, one of which, S, is shewn in the diagram. The sum of the surface of all these slits or openings is equal to the area of the opening of the collar *o o*, in which the cylinder *n n* works. When the steam acquires a sufficient degree of elastic force to raise the valve (that is, the cylinder *n n* with its cover *m*, and the rod R,) and whatever weight it may be loaded with, then the openings S, getting above the steam-tight collar *o o*, allow the steam to pass into the steam box C. The quantity of steam that passes is proportioned to the elastic force it has acquired, and the weight with which the valve is loaded; and the rise of the openings S above the collar *o o*, will be in the same proportion. This valve may be loaded in any of the usual methods; but Mr. Woolf prefers the one shewn in the drawing, in which the upper part of the rod R is joined by means of a chain to a quadrant of a circle Q with an arm projecting from it, as represented in the plate, and which carries a weight Z, that may be moved nearer to or farther from the centre of the quadrant, according as the pressure of the valve is wished to be increased or diminished. As the valve rises, the weight moves upwards in the arch *n n*, giving an increased resistance to the farther rising of the valve, proportioned to the greater horizontal distance from the centre of Q, which the weight attains by its side in the said arch, the said distance being measured in the line O P passing through the centre of the weight. Thus, if the weight Z presses with a force equal to twenty pounds on the square inch of the aperture in O O in its present position, it will, when it rises to the position *i*, press with a force equal to thirty pounds, and at P, with a force equal to forty pounds on the square inch, so that the rod Q Z may be made to serve at the same time as an index to the person who attends the fire, nothing

more being necessary for this purpose than to graduate the arch described by the end of the rod Q Z. In the side of the steam box C there is an opening N, to allow the steam to pass from it by a pipe or tube to the steam engine, or to any secondary boiler, or for the purpose of conveying and applying it to any other vessel or use to which steam is applicable.

Hornblower's second Rotative Engine differs materially from his former one; it is represented in the annexed figures, and consists of

A vessel in which the steam operates, made of cast-iron, extremely resembling a globe, flatted at the poles, (see fig. 1) which shows one of its sides, the other being similar to it. Fig. 3. is a representation of the parts of the machine which move round within the steam vessel, and fig. 2. represents the interior of fig. 1, with its lid removed. The pipe A, at fig. 1, receives the steam from the boiler, to which is connected a valve box, of any usual construction, by which to regulate the admission of steam. At B the eduction pipe is connected, leading from the upper apartment to the condensing apparatus, and turning in such a direction as may be most convenient for the discharging pump to be wrought by means of an arbor, turned by the axle of the machine; on which arbor is a small fly-wheel, for the purpose of regulating the inequality of the crank to which the pump rod is attached. D D is a middle part of the steam vessel, furnished with flanges for the purpose of screwing it to E E, and also for receiving the lid; by which means the partition within is secured to its place, in the middle of the machine, and the lid may easily be removed for the purpose of rectifying and repairing the internal structure. G is the square part of one end of the axis of the machine, over which is placed a gland H, divided into parts, in order that it may be put on over the square, and properly embrace the round part of the axis. Within this gland is a stuffing box, for the purpose of keeping the axle both air and steam tight. In one side of the lower apartment of the steam vessel is a small opening, secured by a lid, for the purpose of cleaning that part of the machine.

(*Hornblower's Engine.* 1804.)

Fig. 2 represents the partition within the steam vessel, which may be made either of brass or iron, or of both those metals combined. B B is the lower flange, the upper part being taken away. C C are the two openings or passages for the vanes: these the inventor calls vane-ports, and to obtain a proper idea of their figure, it must be observed that the largest vane-port is formed by the exterior portions of two cones *z*, and at *y*, by a portion of the concave part of a sphere. The extent of this passage throughout must at least be equal to ninety degrees of a circle, and the vanes of a sufficient width, so that two of them may always make their entrance into the vane-ports before the other two make their exit. The edge, *c c*, may, therefore, be supposed to descend into the lower apartment one half of its depth, and to rise the other half to meet the eye; but it is not necessary that *z* be so deep all the way as *y*, but converge towards the centre of the machine. This is the ascending vane-port; the descending one is included between D D, which are rabbets or seatings for receiving a packing; and *x* represents a rising edge, so as to obtain a depth at least equal to the thickness of the vanes; one half of which edging is below, and the other half above the main axis. These edges receive two metal plates, fixed down with screws on them, for the purpose of confining the packing. The part E is also formed spherically, and is provided with a packing groove, which meets the edge of metal in the middle of the vanes, *k*, Fig. 3. F F is the main axle of the machine, laid in its place without the vanes; one end of which is to perform the work required, and the other is applied to the discharging pump. At D D the packing extends to W W, so as to embrace the nave as well as the descending vane, by which means both the nave and the vanes move steam-tight in their revolutions. *v v v v* is that part of the partition which forms a plane at the axis of the globe, and is secured in its place by being seated in a rabbet with the usual jointing materials on the interior margin of the steam vessel. G G are two brasses let down into the partition, and they are raised or depressed by screws, as adjustment may require.

At *t t* spaces are left for packing round the axle: and the upper brasses which keep down the axle serve also to keep it in its place. At H H are the stuffing boxes mentioned in fig. 1; they have a division plate of metal in them, so that *s s* being supplied with steam from the valve box, the packing of each side of these vacuities is rendered air-tight. The manner in which the partition and vane-ports are constructed, is by rivetting the two parts *v v v v*, together, by means of flanges at I I, first having mounted them on an axis, to correct, by turning, (either by hand or otherwise,) the want of smoothness and truth from the casting; and when this is done, the main axle is fixed to its place as a guide by which to set up the four vanes, as at fig. 3, where, by a mere inspection, it is plain how this is performed. The open vane exhibits a frame of metal, which receives a plate on each side: these plates, with the edge of metal, K, cast with the frame, form grooves and vacuities to receive the packing. The nave being hollow receives two iron axles, which are curved in the middle, and there cross each other.

The manner in which they receive the vanes is shown by the figure; also how the packing renders them steam-tight on the spherical part of the nave, and that when one of them is moved, its opposite vane on the same axle must also be moved. The main axle is turned true by rivetting the two parts together at the nave, and re-rivetting them after the cross axles are set in their places. All the several parts of the machine being then put in their respective situations, it is very evident that when steam is admitted into the lower apartment, the rising vane, which occupies the largest passage, must overpower the other in its descent; and that, if by any means one of the vanes be turned a quarter of a revolution, it must at the same time carry with it the one which is connected on the opposite side of the nave; and this turning is effected by fixing with screws a block of wood, on the partition at K, in the form of a strong bracket. This block will not permit the ascending vane to pass it without being turned on its edge, by which means the one below is turned at the same time,

to present its broad surface to the large vane-port. It may be necessary to remark, that when the machine is to be set at work, the steam is not admitted into the upper apartment of the vessel, to exclude the air, but enters immediately from the valve box to the eduction or discharging pipe, in order to preserve the grease which is made use of to lubricate the internal moveable mechanism of the engine.

We cannot express our opinion on this ingenious machine better than in the words of Dr. Gregory, who says—

"Is there not some ground for fear that in this contrivance, besides the force lost by the action of the steam upon the edges of the vanes, there will be considerable loss arising from the greater friction attending its operations than those of a common steam engine? In this steam wheel there will be a great quantity of rough surface (that of the stuffing) exposed to frequent contact, and consequent resistance to the moving from the fixed parts; besides, as the stuffed parts are here of great extent, with regard to the magnitude of the machinery, and exhibit rapid variations of shape, they may, when brought into constant work, be found difficult to keep in order."*

Mr. R. Wilcox, of Bristol, obtained a patent, in 1804, for lessening the consumption of fuel, by using steam of greater elasticity than common: he proposed in some instances to raise his steam to the pressure of 150 pounds on the square inch.

Mr. Woolf's steam engine is a most ingenious application of a property which steam possesses: it is founded on a very important discovery which he made respecting the expansibility of steam when increased in temperature beyond the boiling point, or 212° of Fahrenheit's thermometer. It had been known for some time (and for this discovery the world is indebted to Mr. Watt,) that steam, acting with the expansive force of four pounds the square inch against a safety valve exposed to the atmosphere, is capable of expanding itself to four times the volume it

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* Gregory's Mechanics. Art. Steam Engine.

then occupies, and still to be equal to the pressure of the atmosphere. Mr. Woolf discovered that, in like manner, steam of the force of five pounds the square inch can expand itself to five times its volume; that masses or quantities of steam, of the like expansive force of six, seven, eight, nine, or ten pounds the square inch, can expand to six, seven, eight, nine, or ten times their volume, and still be respectively equal to the atmosphere, or capable of producing a sufficient action against the piston of a steam engine to cause the same to rise in the old engine with a counterpoise of Newcomen, or to be carried into the vacuous part of the cylinder in the engines of Messrs. Boulton and Watt; that this ratio is progressive, and nearly (if not entirely) uniform; so that steam of the expansive force of 20, 30, 40, or 50 pounds the square inch of a common safety valve, will expand itself to 20, 30, 40, or 50 times its volume; and that, generally, as to all the intermediate or higher degrees of elastic force, the number of times which steam of a given temperature can expand itself is nearly the same as the number of pounds it is able to sustain on a square inch exposed to the common atmospheric pressure; provided always that the space, place, or vessel, in which it is allowed to expand itself, be of the same temperature as that of the steam before it be allowed room to expand.

Respecting the different degrees of temperature required to bring steam to, and maintain it at different expansive forces above the weight of the atmosphere, Mr. Woolf found, by actual experiment, setting out from the boiling point of water, viz. 212°, at which degree steam of water is only equal to the pressure of the atmosphere; that, in order to give it an increased elastic force equal to five pounds the square inch, the temperature must be raised to above 227½, when it will have acquired a power to expand itself to five times its volume, still equal to the atmosphere, and capable of being applied as such in the working of steam engines, according to the invention; and with regard to various other pressures, temperatures, and expansive forces of steam, the same are shown in the following table:—

	Pounds per square inch.		Degrees of heat.		Expansibility	
Steam, of a greater degree of elasticity than the atmosphere, acts with a force of	5	At a temperature of	227½	it possesses a power of expanding itself to	5	times its volume, and continue equal to the pressure of the atmosphere;
	6		230¼		6	
	7		232¾		7	
	8		235¼		8	
	9		237½		9	
	10		239½		10	
	15		250½		15	
	20		259½		20	
	25		267		25	
	30		273		30	
	35		278		35	
	40		282		40	

and so in like manner, by small additions of temperature, an expansive power may be given to steam, to enable it to expand to 50, 60, 70, 80, 90, 100, 200, 300, or more times its volume, without any limitation but what arises from the frangible nature of every material of which boilers and other parts of steam engines have been or can be made: and prudence dictates that the expansive force should never be carried to the utmost the materials can bear, but rather to be kept considerably within that limit.

Having thus briefly explained the nature of Mr. Woolf's discovery, we shall proceed to give a description of his improvements grounded thereon. Mr. Woolf, in his specification, states,—that in describing his invention, he has found it necessary to mention the entire steam engine and its parts, to which, as an invention well known, he neither can nor does assert any exclusive claim: he observes, however, that from the nature of the aforesaid discovery and its application, there can be no difficulty in distinguishing his said improvements from the improved engine of Mr. Watt, as to its other common and well-known parts; and then gives the following account of an engine, embracing his new improvements.

"If the engine be constructed originally with the intention of adopting my said improvement, it ought to have two steam vessels of different dimensions, according to the

temperature or the expansive force determined to be communicated to the steam made use of in working the engine; for the smaller steam vessel or cylinder must be a measure for the larger. For example: if steam of forty pounds the square inch be fixed on, then the smaller steam vessel snould be at least one fortieth part the contents of the larger one; each steam vessel should be furnished with a piston, and the smaller cylinder should have a communication both at its top and bottom (top and bottom employed here as relative terms, for the cylinders merely may be worked in a horizontal, or any other required position, as well as vertical); the small cylinder, I say, should have a communication, both at its top and bottom, with the boiler which supplies the steam, which communications, by means of cocks or valves of any construction adapted to the use, are to be alternately opened and shut during the working of the engine. The top of the small cylinder should have a communication with the bottom of the larger cylinder, and the bottom of the smaller one with the top of the larger, with proper means to open and shut these alternately by cocks, valves, or any other well-known contrivance. And both the top and bottom of the large cylinder or steam vessel should, while the engine is at work, communicate alternately with a condensing vessel, into which a jet of water is admitted to hasten the condensation, or the condensing vessel may be cooled by any other means calculated to produce that effect. Things being thus arranged, when the engine is at work, steam of high temperature is admitted from the boiler to act by its elastic force on one side of the smaller piston, while the steam which had last moved it has a communication with the larger steam vessel or cylinder, where it follows the larger piston, now moving towards that end of its cylinder which is open to the condensing vessel. Let both pistons end their stroke at one time, and let us now suppose them both at the top of their respective cylinders, ready to descend; then the steam of forty pounds the square inch entering above the smaller piston, will carry it downwards, while the steam below it, instead of being allowed to escape into

the atmosphere, or applied to any other purpose, will pass into the larger cylinder above its piston, which will take its downward stroke at the same time that the piston of the smaller cylinder is doing the same thing; and while this goes on, the steam which last filled the larger cylinder, in the upward stroke of the engine, will be passing into the condenser during the downward stroke. When the pistons in the smaller and larger cylinder have thus been made to descend to the bottom of their respective cylinders, then the steam from the boiler is to be shut off from the top and admitted to the bottom of the smaller cylinder, and the communication between the bottom of the smaller and the top of the larger cylinder is also to be cut off, and the communication between the top of the smaller and bottom of the larger cylinder; the steam, which in the downward stroke of the engine filled the larger cylinder, being now opened to the condénser, and the communication between the bottom of the larger and the condenser shut off; and so on alternately, admitting the steam to the different sides of the smaller piston, while the steam last admitted into the smaller cylinder passes alternately to the different sides of the larger piston in the larger cylinder, the top and bottom of which are made to communicate alternately with the condenser.

"In an engine working with the improvements which have been just described, while the steam is admitted to one side of the piston in the smaller cylinder, the steam on the other side has room made for its admission into the larger cylinder, on one side of its piston, by the condensation taking place on the other side of the large piston, which is open to the condenser; and that waste of steam which takes place in engines working only by the expansive force of steam, from steam passing the piston in the smaller cylinder, is received into the larger.

"In such an engine, where it may be more convenient for any particular purpose, the arrangement may be altered, and the top of the smaller made to communicate with the top of the larger, and the bottom of the smaller with the bottom of the larger cylinder; in which case, the only dif-

ference will be, that when the piston in the smaller cylinder descends, that in the larger will ascend, which, for some particular purposes, may be more convenient than the arrangement before described.

It will at once be seen that this engine of Mr. Woolf's is the same in principle as Mr. Hornblower's, described at page 97, which we have shewn to possess no advantage, in point of *power*, over the expansive engine of Mr. Watt. If any advantage be possessed by the double cylinder principle, it is, that the force is more uniform in it, than in Mr. Watt's; for in the latter, if the force begin at 2, it ends at 1; whilst in the former, if it begin at 2, it ends at 1. 5. It was on account of this great variation of power, that Mr. Watt, in his patent of 1782, described such a number of methods for regulating the action of the engine.

Mr. Woolf has erected several engines on this principle, which have been found to perform the required work with a considerable saving of fuel. In 1815, the effects of some of those engines were brought into comparison with those on Mr. Watt's expansive principle, at Cornwall. Regular reports have since been made by Messrs. I. & J. Lean, general superintendents at some of the Cornwall mines, by which it appears that there is an immense difference, in the effect of the engines of Mr. Watt and Mr. Woolf, compared to the quantity of coals consumed by each; the saving being in Mr. Woolf's favour. It should be observed, however, that Mr. Woolf's engine has been of more recent construction, and consequently has all the advantages of improved workmanship and reduced friction; furthermore, that Mr. Woolfs boilers are undoubtedly calculated to raise a larger quantity of steam, by a given quantity of fuel, than those on the common principle; and lastly, that Mr. Woolf's carries the expansive principle to a much greater extent, by introducing the steam into the smaller cylinder, at a much greater pressure per square inch, than Mr. Watt ever professed to do; from which it will be evident that the advantages of saving fuel, mentioned before, will be obtained.

Mr. Woolf, in his patent of 1805, proposed to use oil or

fat to surround his cylinders in place of steam, previously used to prevent the waste of caloric. He also proposed to surround his piston with mercury, or employing upon it such a column as might counterbalance the pressure of the steam. But Mr. Woolf possesses much greater claim to notice by his invention of a most excellent method of tightening the packing of pistons. It is well known that the piston of a steam engine, by continued working, becomes easy, and by allowing steam to escape past it, occasions a considerable waste; so that it is necessary in the common plan to take off the top of the cylinder, in order to get at the screws, or supply the piston with fresh packing.

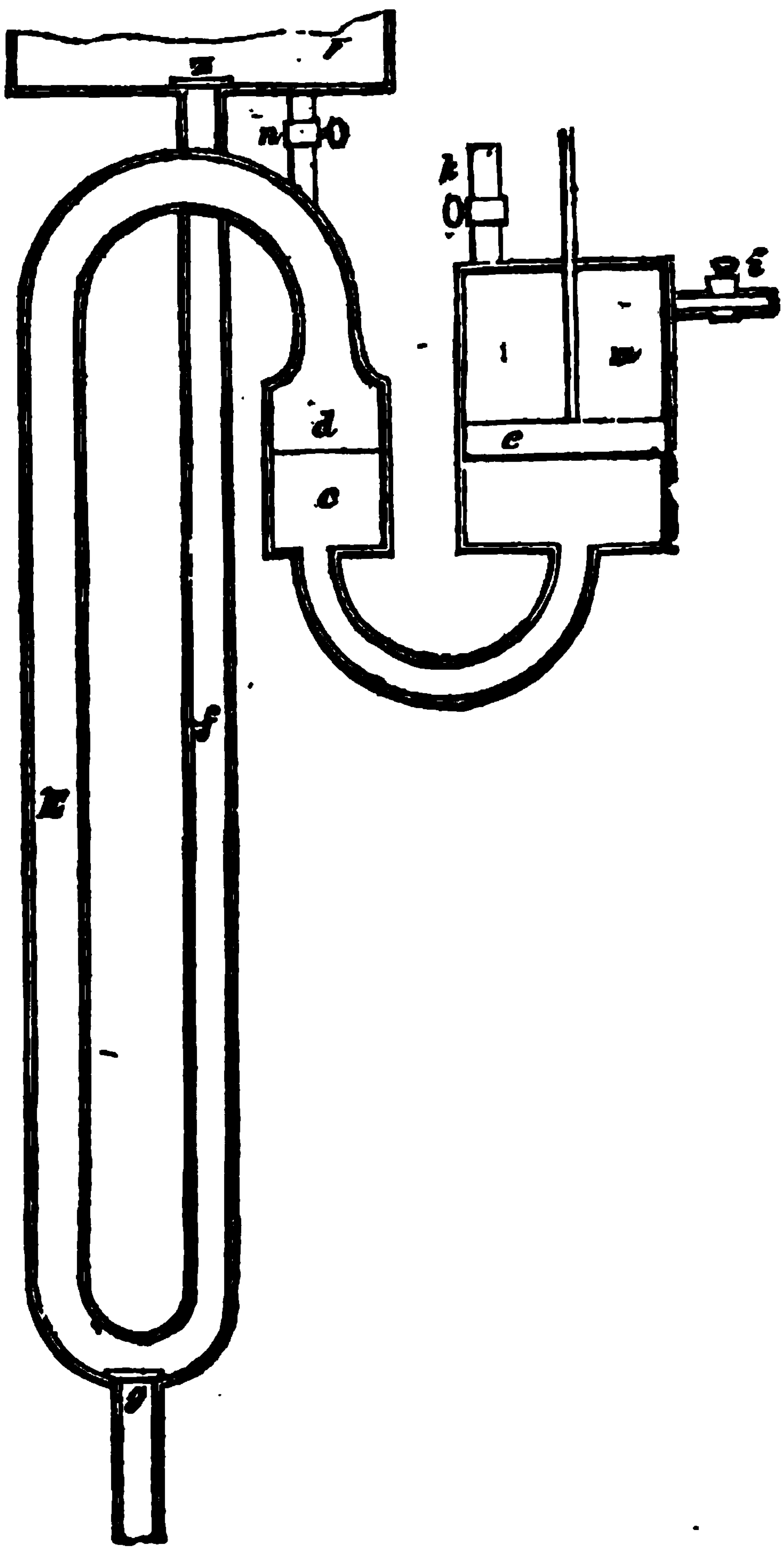
Mr. Woolf obviates this difficult and laborious operation by a method of tightening the screws, without in the least disturbing the cover of the cylinder, which he thus effects.

He fastens each of these screws into a small wheel *c c c c c*, as shewn in the annexed figure, which are all connected with each other by means of a central wheel *d d*, which works loose upon the piston rod in such a manner, that if one of the small wheels be turned, it turns the central wheel, and the latter turns the other four. The one that is to be first turned is furnished with a projecting

square head, which rises up into a recess in the cover of the cylinder. This recess is surmounted by a cap or bonnet, which being easily taken off, and as easily put again in its place, there is little difficulty in screwing down the packing at any time. The parts are so clearly expressed in the drawing, that no further description is necessary to make any person comprehend it.

The other method is similar in principle, but a little different in construction. Instead of having several screws all worked down by one motion, there is in this but one screw, and that one is a part of the piston rod: on this is placed a wheel of a convenient diameter, the centre of which is furnished with a female screw. This wheel is turned round, *i. e.* screwed down, by means of the pinion *o*, which is furnished with a square projection head, rising into a recess of the kind already described. The ring is prevented from turning with the wheel by means of two steady pins.

Mr. James Boaz, of Glasgow, obtained a patent in 1805, for a machine for raising water on a plan somewhat similar to Savery's.



(*Boaz's Engine.* 1805.)

a is the steam cylinder; *i*, the pipe from the boiler, having a stop cock; *k* a waste steam cock; *e*, a floating piston attached to a piston rod. *E* a pipe which generally contains hot water; *f* water pipe, having a valve at *g* immersed in the well, and delivering the water into the reservoir *v*, through a valve *z*. The air which accumu-

lates in the receiver escapes at *n*; *v*, the raised water cistern; *d*, rarifying or exhausting vessel.

The engine being filled with mercury, between the line *d*, and the lower part of the cylinder *a*, and the remainder with water, shut the air valve *z*, and open *i*; the steam from the boiler will rush into the receiver, and pressing on the surface of the piston forces the mercury up into the exhausting vessel *d*. The water above *c*, and in the pipes *E f*, will be forced up into the cistern *V*, in a quantity nearly equal to the space occupied by the steam in the receiver. When the piston has been depressed as far as is necessary for its stroke, the self-acting mechanism attached to its rod, shuts *i*, and opens *k*; and the mercury being now at liberty to act by its gravity, descends from the exhausting pipe, and raises the piston to its first position; and the steam which pressed it downwards being now allowed to flow into the atmosphere, the fall of the mercury from *d* into *a*, leaves a vacuum in *d*, into which the water in the well is pressed by the atmosphere, and again fills it. The valve at *g*, prevents its return to the well in the operation of forcing; and the valve *z* prevents its fall from the cistern, when the vacuum is made in *d*.*

The ingenuity by which a vacuum is obtained in this engine will be quite apparent. The great difficulty in all the modifications of Savery's engine had hitherto been, that great waste of steam was occasioned by its being exposed to the cold water, on the surface of which it had to exert its force. But in this machine, such an exposure is avoided, and the apparatus is as simple and free from friction as anything of the kind we have ever known. We have never yet seen mercury used effectively in large quantities in a steam engine; but, should its application here be found to be attended with no great waste, we doubt not but that this engine would answer the purpose of the inventor.

In the year 1805, Mr. John Trotter, of London, obtained

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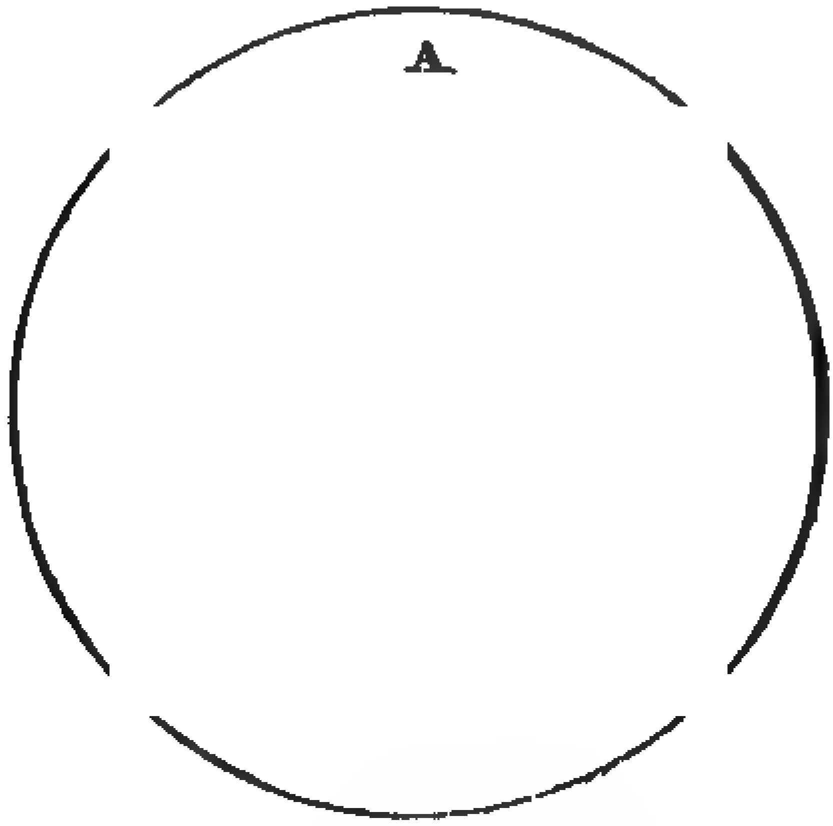
* Repertory of the Arts.

a patent for a Rotative Engine, which may be thus illustrated.



(*Trotter's Engine.* 1805.)

A, a circular piece called the outer barrel. B the inner barrel. C, a circular piece called the eccentric. D, a piece called the sweep, which shuts completely across the space between the inner and outer barrels, so as to intercept the communication in that part. There are caps or covers at each end of the pieces, which close the space between the two barrels, and serve, by grooves or other well-known fittings, to keep the other parts in their respective places.

The situations and motions of the parts herein enumerated are as follow :—1st, The barrels are concentric. 2ndly, The sweep is capable of moving or revolving (either by absolute or rotative motion) through the space between the barrels; it may be either separate from the barrels, or it may be fixed to either or both of them, and in the last-mentioned cases, the barrel or barrels to which the sweep shall or may be so fixed, will necessarily move along with it. The sweep is so well fitted or fixed that

no fluid shall pass through the places of its opposition or junction with the barrels or caps, or as that the quantity suffered to pass shall be inconsiderable. 3dly, The eccentric is of such a diameter and so wrought, that its concave and convex surfaces shall touch the inner and outer barrels, and that the places of contact shall not admit any fluid to pass between the eccentric and each barrel severally, or at least, that the quantity which may so pass shall be inconsiderable. The eccentric is capable of rotation in its own plane or periphery, but not otherwise with relation to the caps; and it has a long perforation through which the sweep is put, consequently the sweep and eccentric will always move together.

It may be pointed out, as distinguishing characters of this engine, that, whenever the sweep is moved, the space which is comprehended between the barrels and the eccentric, and the posterior or hinder surface of the sweep, will be continually enlarged, and that the space which is in like manner comprehended between the barrels and the eccentric, and the anterior or fore-surface of the sweep, will be continually diminished, excepting that, soon after the sweep has passed at or near the places of contact between the eccentric and the outer barrels, the posterior space will be suddenly diminished by the separation of all that portion which was comprehended between the eccentric or outer barrel, in consequence of the place of contact having come to be behind the sweep. And also, that soon after the sweep has passed at or near the place of contact between the eccentric and the inner barrel, the posterior space will be suddenly diminished by the separation of all that portion thereof which was comprehended between the eccentric and the inner barrel, in consequence of the place of contact having come to be behind the sweep; and the said portions so separated will then respectively become portions of the anterior spaces, in consequence of the interval or distance which will at the same time be formed between the eccentric and the barrel immediately before the sweep. Whence it is manifest, that if any fluid be forced by gravity, elasticity, or otherwise, through one or

more apertures from without into the space on one side of the sweep, that pressure will carry the sweep forward and the eccentric along with it, together with such barrel or barrels, as by the construction shall or may be fixed to the sweep; and, moreover, if there be any one or more other apertures communicating from the opposite side of the sweep, in order to allow the said fluid to escape, or be carried off or condensed, or otherwise disposed of, all such portions of the said fluid as, by the change of situation of the sweep herein-before described, shall be separated from occupying part of the space behind the sweep, and shall come to occupy part of the space before the same, will, in fact, so escape or be carried off, or condensed, or disposed of, and the rotatory motion of the engine will be kept up, and may be applied as a first mover to other works, so long as a due supply of the said fluid shall be afforded.

It is manifest, that in case the rotatory motion of the said engine be produced by any force not applied to its internal parts in the manner herein-before described, and any fluid be admitted to communicate with the posterior space within the same, the said fluid so admitted will flow into or be absorbed in the said space, which becomes continually enlarged, and will afterwards be transferred to, and drawn out of the anterior space, which becomes continually diminished as aforesaid: and that, in this application, the said engine may be used to raise or give motion to fluids in any direction whatever.*

This rotative engine possesses originality and ingenuity, which cannot be said of many which we have enumerated. Our readers will perceive that the reasons which we have given for the failure of many of such like attempts may be applied to this apparatus with no less truth. Friction has been generally the cause of their failure, and here that friction appears more than double of almost all we have yet noticed, for to the friction of the sweep we must add that of the ends of the concentric and eccentric cylinders, which are packed at their peripheries, besides the friction of the

* Specification of Patent

points where they are in contact with each other. If machines of this nature, when encumbered with only one inner cylinder, have been inferior in effect to the reciprocating engines, it cannot require much discernment to see that, in this instance, where two such cylinders are used, the power must be trifling indeed. Further, it may be added, that all the parts would be liable to wear out of the form in which they were first constructed, so that no packing could preserve them steam-tight. This would take place in a short time, at the sides of the cavity formed in the eccentric cylinder, for allowing the sweep to slide through it.

We consider the machine we are about to describe, invented by Mr. Andrew Flint, (and patented about the same time), as liable to the objections we have just mentioned. The difficulty of packing indeed (all others out of the question) appeared to be an insuperable barrier to its application.

The annexed fig. 1, is a horizontal section through the body of the engine. Fig. 2, which is a vertical section of the same, in the line *w x*, of fig. 1; the same parts in each figure being marked with the same letter. C is the outer cylinder of cast iron, or other proper metal; D the bottom plate of the same. E the top plate, firmly fastened down by screws passing through the projecting flangs at *f f*. G is the inner cylinder, hollow, and divided by a partition at *h*. The two cylinders, C G, must be turned very true, and placed exactly concentrically. A B is the hollow central shaft, cast in one piece with the cylinder G, and forming an axis to it, turning in the stuffing boxes I I. K and L are two valves, each consisting of a top and a bottom plate *m m*, (see fig. 4), connected by a portion of a solid cylinder *n*. The plates *m* are sunk into the plates D and E, so as to lie flush with their inner surfaces; and the connecting piece *n* lies in and fills the cavity prepared for its reception in the outer cylinder C, at *o*, and thus completes the inner surface of the same.

P is the steam float, firmly attached to the cylinder G, and revolving with it through the circular passage left between the two cylinders; which passing it accu-

(*Flint's Rotary Engine.* 1805.)

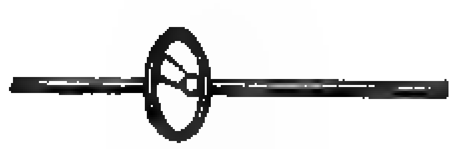
rately closes by means of a packing composed of hemp, tallow, or other substances used in steam engines for that purpose. *qqqq* shew the manner of packing the top and the bottom plates of the cylinder G, and of the valves K and L, to prevent the escape of the steam between them, and the top and bottom plates of the outer cylinder. This is alike in all these instances, but will be most readily understood by comparing fig. 1. with fig. 3, which shews the parts to a large scale. *r* is a circular groove sunk in the inner surface of the plates D and E, and concentrically to the axis of the cylinder G, and of the valves K and L respectively. In this groove is placed a metal packing ring *t*, and it is then to be filled up with a packing, against which the surfaces of the said plates of G, K, and L work; and this packing may be tightened in any degree necessary by the screws *ssss*, which press upon the back of the packing-ring. It is proper to notice, that these circular rings of packing should, in a small degree, intersect each other at I, to prevent the steam from escaping between them into the vacuous parts of the engine. Q Q are chases filled with packing, to prevent a similar escape of the steam behind the valves. The steam-float P is to be packed in its place by means of the circular aperture in the top plate E, which aperture must be securely closed by a plate fitted into it, and confined by a strong dog; or the packing may be introduced by holes in the outer cylinder C, which may be closed in a somewhat similar manner; but this mode is considered as less secure, when steam of great elasticity is employed. It is evident, that if steam of sufficient force be admitted through the hollow shaft A, it will fill the lower division of G, and passing through the hole 6, into the circular passage already described, where (the valve L being first placed across the said passage,) it will act upon the steam-float P, with a power proportioned to its elasticity and the area of P, and thus face it round till it passes the valve K, the steam before it finding a vent by the hole 7, into the upper division of G, and so through the shaft B into the condenser. If now the valve K be shut, the re-action, as it is termed, will take place against it, and the

valve L may be opened to allow free passage to the steam-float. These valves are placed in the required position by the working gear.*

It is our business next to describe the inventions of Mr. R. Wilcox, of Bristol, whom we have already noticed in another part of this section. He obtained a second patent in 1805, for a number of rotative engines, which are, in our opinion, exceedingly ingenious. The work entitled Stuart's History of the Steam Engine, has passed over the contrivances of this gentleman, by remarking that they vary from Mr. Flint's only in some trifling alterations of the cocks and steam pipes. But it will be seen that this is incorrect, as some of the plans described differ entirely, not only from Mr. Flint's, but from every previous attempt of the kind.

Fig. 1. is a vertical section of one of his plans, as attached to the common condenser, for the purpose of shewing one of the most simple and compact arrangements, where the steam is condensed. A, the outside case or cylinder, fixed to the framing of the condensing cistern, or any other more suitable and convenient framing that the engineer may find most appropriate or suitable to the locality of the premises, where the engine is to be erected. B B, the inside or revolving cylinder, attached to and connected with the vertical shaft, which is the first mover, and which gives a rotative power to any description of machinery requiring the same, through the medium of a spur wheel fixed to the said shaft, when a vertical motion is required; or with a bevil-gear wheel, where a horizontal motion is wanted. C C, moveable pallets, gates, or valves, for regulating the operation of the steam in the engine; one of the said pallets, &c. is attached to the fixed cylinder A, and the other to the interior cylinder B, as is more distinctly seen in fig. 2, and the references annexed. D, the steam valve for the admission of steam between the said pallets. E, the exhausting valve, for the egress of steam. The gear required for opening and shutting the valves D

* Specification of Patent.



(*Wilcox's Engine.* 1806.)

and E, and for opening and shutting the said pallets or gates, C C, is so nearly similar to that of common engines, tha it would be useless to describe it further than that the said valves D and E require to be opened and closed at the same time, whereas, in general, they are opened and shut alternately by the plug tree, or other simple and well-known means. F, the top of the cylinder, composed of a ring of metal, for pressing the packing round the moveable cylinder; the lid is screwed down with screws, as is usual in securing the lids or tops of cylinders. G G, two rings of metal pressed by screws, from a lever secured to the top of the cylinder F, for compressing the packing, and securing the joint of the cylinders A B. H H, a circular channel, into which the revolving cylinder B works, for the purpose of preventing the ingress of air or other fluids into or by the said interstice or channel, and which is packed with hemp and grease, and pressed in such a manner with a ring as thereby to render the engine more efficient, by keeping it perfectly tight. 1, the common condenser, the air pump of which is wrought by studs or stops projecting from the horizontal shaft, or any other simple or effectual way, which the engineer may think proper, as is more distincly seen in fig. 3, which is the end view of the shaft, and the side view of the piston rods; the operation of which is so obvious, as not to require elucidation. Fig. 2 exhibits a bird's eye view of fig. 1, with the top of the cylinder and compressing rings removed, to show the operation or apparatus for opening and closing the pallets, gates, &c. and also part of the flanges removed to show the situation of the valves. The letters of reference in this case of fig. 2, are placed upon the same parts of the engine as in fig. 1, which it would be superfluous to recapitulate. C C, the pallets, &c. formed of two or more pieces of metal; one part of the said pallet is permanently secured to each cylinder A and B, whilst the other part or parts turn on a joint or hinge; which said joint or hinge is made steam-tight or secured, together with the whole of the edges coming in contact with the cylinder, with a hempen cloth stuffed wadded, or folded together, or by other similar

materials, capable of stopping the passage of steam, and which must be screwed or otherwise fastened on the front of the said pallet; and by the pressure of the steam it is pressed or brought in contact with the said pallet or cylinders, and thus it effectually prevents the escape of steam or other fluids, by or with which the engine is wrought. K K, two racks and pinions communicating by a straight and parallel bar, working through a stuffing box in the sides of each cylinder, whereby the said valves are opened and shut, whilst passing each other, from the external part of the engine, by a piece projecting from the upper or lower part of the fixed cylinder, which may be placed at the option of the engineer; which said piece in its passage comes into contact with the gear connected with the said pallets, and thereby with any of the well-known simple methods or gear used for the opening and shutting of valves in the present steam engines. The gates, &c. of the engine are opened and shut as occasion requires. L, (fig. 2,) exhibits a second gate, &c. which in this case slides backwards against a straight parallel surface during the time the pallet in the revolving cylinder is passing, when the said gate is sliding by the gear against the revolving cylinder, as in the drawing. The said gates may be opened and closed in a variety of ways, such as a spindle ground into the bottom of the fixed cylinder, and connected by a link to the gate internally, or a crank or compound lever may be applied, instead of the rack and pinion, externally.

In another plan, Mr. Wilcox proposes a piston firmly fixed to the interior cylinder, and, instead of gates or pallets, he has a plate of metal, which is drawn into a recess as the piston passes, and returned immediately into the cylinder, so as to become an abutment for the action of the steam.

In this plan, A is the outside stationary cylinder. B, the inner cylinder; C, the top of the cylinder and rings, as in figs. 1 and 2, already explained. D, a plate of metal, as represented by the dotted lines, made very straight, smooth, and parallel, as it respects its thickness. E, a small shaft or axle, working through a box, or a receptacle fixed on

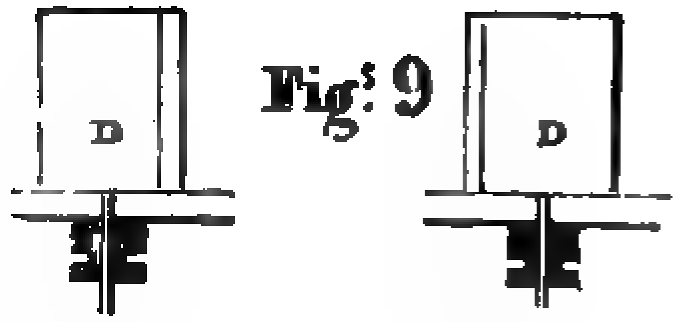


Fig. 9

(*Wilcox's Patent Engines.* 1805.)

the outside of the cylinder A, allowing room sufficient for the said plate to drop clear off to the bottom of the cylinder, whilst an accurate incision is made in the bottom and side of the cylinder, sufficient to admit the said plate D to slide freely up and down, which is effected by a rack and pinion, or lever, or any other simple contrivance attached or connected to the extremity of the shaft E ; by which means the steam is caused to act on the same or a similar principle, as in fig. 1. F, (fig. 4,) presents a second way of producing the same effect, namely, that of raising a plate of metal through an incision made in the bottom of the cylinder A, from a box fixed underneath the cylinder, through the medium of a parallel bar working through a stuffing box, whereby the said plate D is raised or depressed, as the working of the engine requires.

"Fig. 5, is a bird's-eye view of fig. 4, with the same general letters of reference to their respective parts, as in fig. 4. K, the steam passage. L, a passage leading or communicating with the condenser, when the steam is required to be condensed. Here it may be necessary to remark, that, although the plate D be shown as rising upwards, considering it to be the most convenient way, nevertheless, the boxes necessary to receive the plates may be placed above the cylinder, and the plates may be raised in an oblique instead of a perpendicular direction.

"Fig. 8, is the plan of another rotatory engine. A, the outside fixed cylinder. B, the inner or revolving cylinder. D D, two or more pallets, working through a deep stuffing box, and turned by a lever, or other power, from the external part of the engine, alternately flat or edgewise; the piston F is fixed to the revolving cylinder ; E, is the steam passage, that to the condenser not being shown.

"Fig. 10, is a bird's-eye view of a rotary engine, as wrought with a cock or portion of a circle, whereby a similar effect is produced as in fig. 1, by or with a portion of circles: in these figures, 8 and 11, the lids of the cylinders are removed, and a part of the flanges, where the circles or irregular cocks are used, is broken off, to render the working parts conspicuous. A, the outer or fixed cylinder.

(*Wilcox's Engine.* 1805.)

B, inner or revolving cylinder. C C, the pallet, cock, or portion of a circle, fitted accurately into the circle it prescribes; with a spindle working through the top of the cylinder. D, the groove, into or against which the part coming into contact with the revolving cylinder is secured with a piece of hardened metal, in order that the constant friction of the revolving cylinder shall not injure the pallet or cock. E, the passage to the boiler. F, the passage to the condenser. G, the pallet, secured to the working cylinder. In this figure two portions of circles and cocks are introduced, for the purpose of showing clearly their situations in different places, the same as in fig. 10.

"Fig. 11 exhibits a bird's-eye view of a rotatory engine, as wrought by a cock or cocks, which regulate the steam instead of valves, and also act as the principal cock or pallet in the said engine. A, the outer fixed cylinder. B, the inner revolving cylinder, with a fixed pallet. C C, the cocks, which are wrought from the external part of the engine, by a spindle passing through the top. D, a piece of hard metal, introduced into the said cock, to resist the friction of the revolving cylinder, as explained in fig. 10. E, steam passage. F, passage to the condenser."*

The first of Mr. Wilcox's plans (1 and 2) is, as far as we know, perfectly original. Its great complexity has been, no doubt, a great cause of its abandonment; if, indeed, it was ever tried. The number of racks, pinions, gates, pallets, joints, grooves, slides, and stuffing boxes, must instantly impress the mind of every one with an idea of its great inferiority to the most complex reciprocating engine.

The second scheme (4 and 5), it will be perceived, resembles in its general principle one of Messrs. Bramah and Dickenson's engines, a description and plan of which will be found at page 111, of this work. The objections, therefore, which have been made against that plan, will apply equally to Mr. Wilcox's.

* Specification of Patent.

In the third plan (8) we apprehend that a great waste of steam would arise from the difficulty of making the pallets, D, unite sufficiently close at the joints; besides that the complexity would be nearly as great as the first plan.

The fourth and fifth plans (10 and 11) resemble that of Mr. Flint's so nearly, that we doubt not they failed from the same cause.

In the year 1807, Mr. Henry Maudslay, of London, obtained a patent for a Portable Engine, in which he introduced several ingenious improvements on the valves and working parts of steam engines, which tended not only to reduce the friction, but altogether to render them tighter and more compact. The accompanying figure will enable our readers to understand what these improvements were.

A, represents a frame of thin cast iron, for the purpose of fixing the cylinder. B B are two cold water cisterns, of merely sufficient size to admit of easy access to the pumps within them; they communicate with each other by a pipe *a*. C is the cylinder surrounded by a casing (*b*) of copper, or other material. The space between the cylinder and casing is filled with wool, or some other imperfect conductor of heat; D is the piston rod, joined to smaller rods carried down on each side of the cylinder to E, and having an opening or division so as to avoid interfering with the main shaft. These rods are at their lower ends fixed to a wheel F, with a fluted rim: from the centre of which a connecting rod, G, is carried to the end of the crank. The wheel F runs between two guides, *c c*, so as to preserve the rectilineal motion of the rods E, and the piston rod D. H is the crank, a three-throwed one. J, a cross beam for working the pumps P O M; its motion is procured by having a fork underneath it, which embraces one of the cranks H, on which is a roller for reducing friction. By this means the fork, and consequently the beam and pump rods, are reciprocated by the revolution of the shaft. K K is the fly wheel; L is the condenser, containing the air pump M; N is the hot water cistern, and O the hot water pump; P, the cold water pump; Q, the

(*Maudslay's Portable Engine.* 1807.

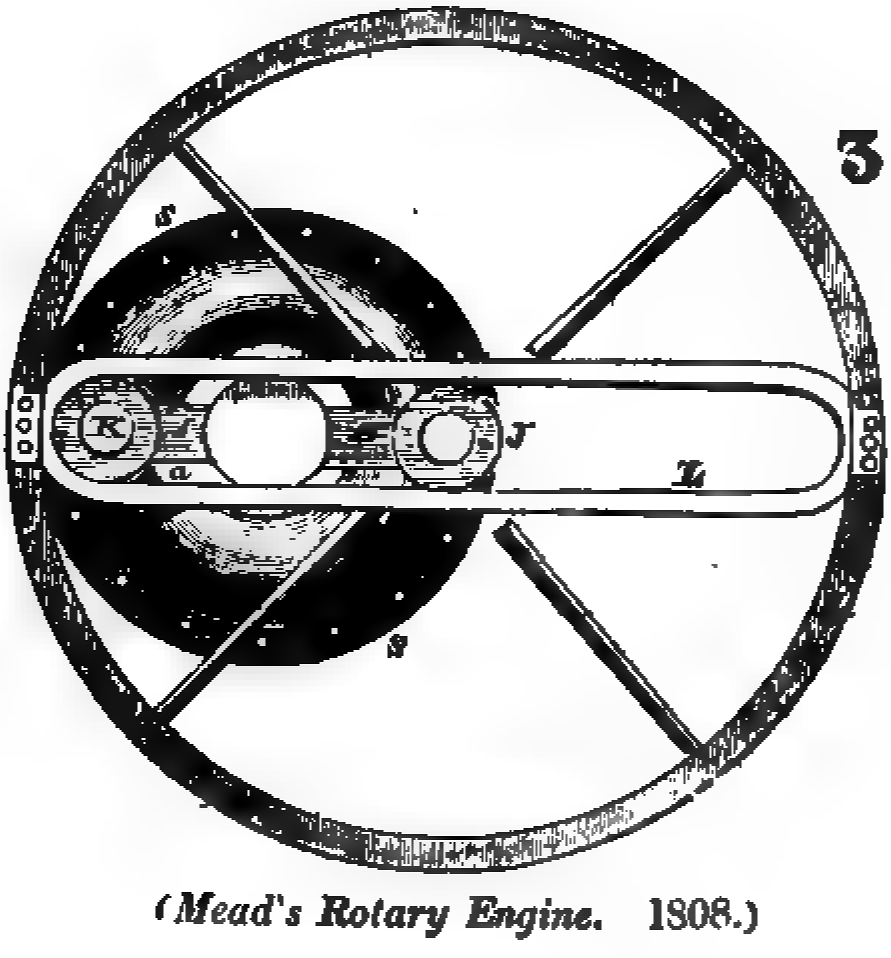
injection cock; R the steam pipe from the boiler to the cylinder; S the eduction pipe. The steam is admitted into the cylinder by a four-way cock, which differs from that generally used by its being considerably more tapered, which effectually prevents it from *jamming* by unequal expansion or contraction, an evil to which the common cock is liable.

There are few machines which display more ingenuity, either on account of skilful arrangement or neatness, than

this; and, as it regards its utility, it need only be said, that long-continued trials have fully established the great excellence of Mr. Maudslay's engine. We do not pass over this machine, therefore, with so short a description on account of any doubt respecting its merits; for were the length of our remarks to be governed by our opinion of the utility of any machine, they would in this instance extend over several pages. But, however beautiful may be the arrangement of Mr. Maudslay's engines, this is not their sole merit; for Mr. M. has, by superior workmanship, and most careful attention to the selection of good materials, obtained the reputation of being one of the best manufacturers of steam engines in the world.

Mr. J. Mead, of Hull, obtained a patent for a rotary engine, in 1808, of which the following is a description.

A and B, fig. 1. are two circular plates or shells of metal, similar in their construction, having their insides turned, or otherwise made very true and correct; A has its outside uppermost, and B its inside uppermost. Each of these circular plates or shells have a flange and semicircular cavity, formed for the reception of the pistons which are afterwards described, and a recess or hollow part formed round its centre for a small circular plate to turn in. Near to the edge of each recess is a small groove running quite round it; in the bottom of each groove is placed a metallic ring, O O, capable of being adjusted by screws on the outside of each shell. At its centre is a hollow pipe or boss, for the reception of the spindles, F and G. The plate A has also two holes, *a a*, fig. 3. to which pipes are fitted, one to convey steam into the shells, the other to conduct it from them into a condenser, or wherever it may be required. C C, two pistons with grooves round them to admit of a packing or wadding. D and E, two circular plates, to which the pistons are connected or made fast. F and G, two shafts or spindles; the spindle G is made hollow to receive the spindle F, which passes through it. H and I, two arms made fast to the two spindles; each arm,



(*Mead's Rotary Engine.* 1808.)

near its extremity, carries a wheel K and J, which are generally termed friction wheels. L, a fly or a regulating wheel, fixed to one end of a shaft or moveable axis, having in its side opposite to its axis a groove running across its diameter for the reception of the friction wheels J and K, which wheels, when the pistons are put in motion, work in it, and give motion to the fly wheel and other machinery which may be connected with it. R R, the hollow plates or bosses for the spindles to work in; S S, flanges by which the shells are fastened together. Fig. 2 is a front view of one of the pistons, with its circular plate, arm, and friction wheel; J, the friction wheel; H, the arm; D, a circular plate, and C the piston. V V V grooves for the reception of the packing or wadding, which is to be made fast therein. When the engine is to be put together, the arms are taken off from the spindles; the spindle F is then to be inserted in the hollow spindle G, which, with their respective pistons, are placed in one of the shells, and the one shell placed over the other; the shells are then fastened together with screws or otherwise, so as just to admit the pistons with their respective plates and spindles to turn round in their channels nearly steam-tight; the arms may then be made fast on the spindles, and the engine erected. Place the direction of its axis in a horizontal or lateral direction, parallel with the direction of the axis of the fly, but nearly as much out of that line as the length of one of the arms, H and I, taken from the centre of the spindle to the centre of its friction wheel, and at such a distance from the fly as to admit of the friction wheels moving freely in the groove on its face. By so doing, the axis of the engine will be placed eccentric with the axis of the fly. The engine may be fixed in an iron or wooden frame, and the fly supported in the same, or a separate frame, in the position before pointed out. If the fly be then turned half way round upon its axis, one of the friction wheels will remain locked or held fast in the groove near its centre, and the piston with which it is connected will remain nearly stationary in the steam chamber, between the holes *a a*, while the other friction wheel, with its arm, spindle, small circular plate

and piston, make nearly one complete revolution, round their common centre of motion, or the centre of the engine. If the motion of the fly continue till it has made one complete revolution round its own axis, the friction wheel, which was locked or held fast in the groove near its centre, will move off in the groove towards the circumference of the fly, and with its arm, spindle, small circular plate, and piston, make nearly one complete revolution round their common centre of motion, or the centre of the engine, and the other friction wheel in its turn remain locked, or held fast in the groove near the centre of the fly, and the piston with which it is connected remain nearly stationary within the steam chamber between holes *a a*; and so on, alternately, as long as the fly continues in motion. Instead of the hollow spindle G, and the solid spindle F, two other solid spindles may be used, by applying one to each small circular plate, and passing them through the opposite pipes or bosses, each having its arm and friction wheel as before, but working in separate grooves mounted on separate axles, and united by wheel work. When the engine is to be set to work by the force of steam, the steam is permitted to enter by one of the pipes into the steam chamber, where, by its elasticity, it will press or act upon both pistons nearly alike; and as one of the pistons is stopped or held fast by the aforesaid methods, the steam cannot pass into the other pipe that way, but will force the other piston round with its small circular plate, spindle, arm, and friction wheel, and put the fly in motion, and continue it as before explained. A similar effect may be produced with a concave globe or sphere, having within it two moveable semi-circular leaves, (as a substitute for the pistons,) with packings at their edges, and united in the centre or axis of the globe with joints or hinges, and having each of them an axis passing through the globe to receive the arms and friction wheels as before described, and with holes and pipes for the admission of steam."*

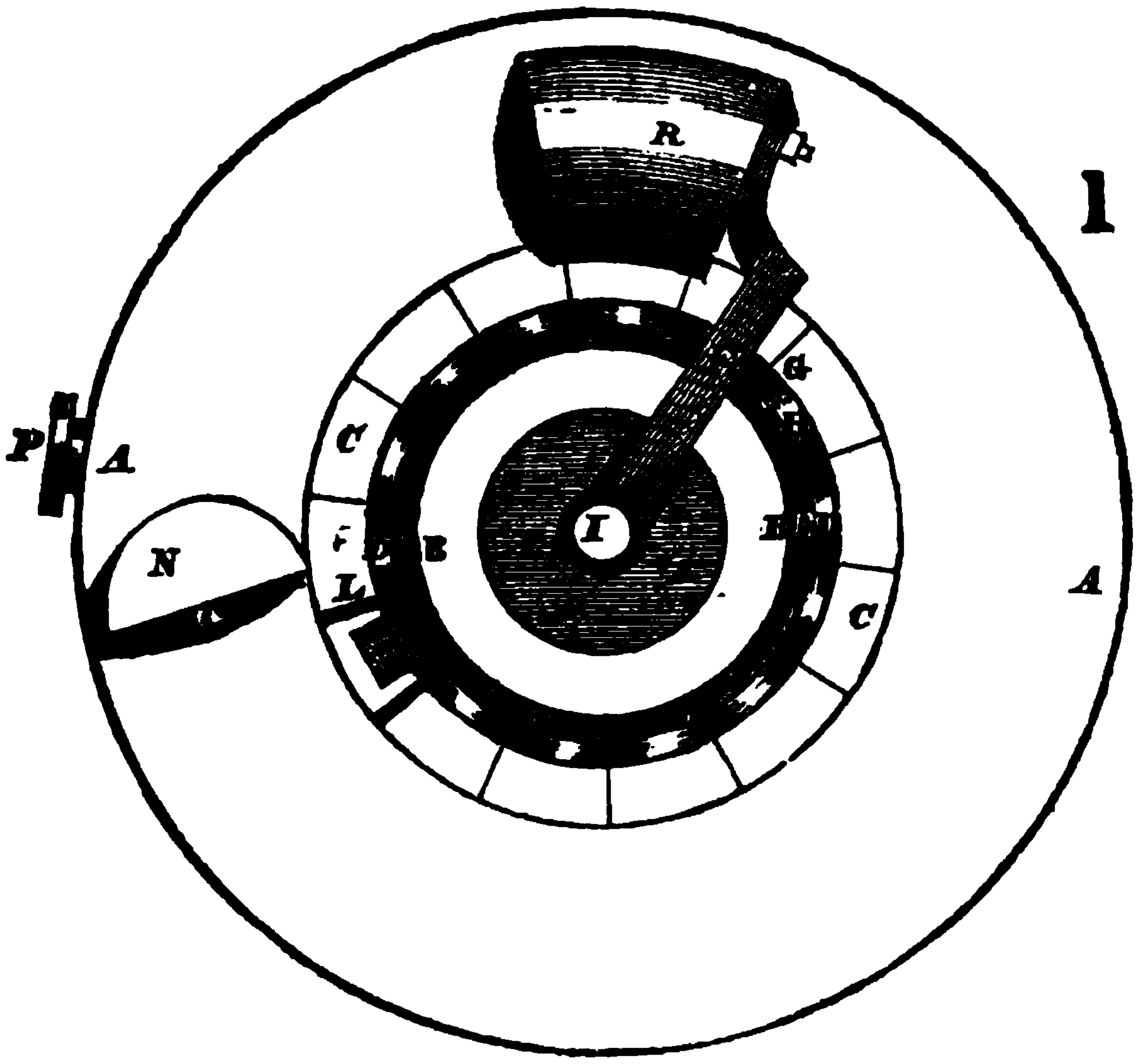
By referring to Hornblower's Engine, described at p 121,

* Specification of Patent.

it will be seen that the principle of the alternate revolution of two pistons is adopted, both in his and in Mr. Mead's; but although there might not be that difference in the latter engine as to merit the name of an original idea, yet it is extremely ingenious; and the method whereby he has endeavoured to avoid the striking of the two diaphragms, is probably the nearest approach to a removal of that evil, which we stated was the probable reason of the abandonment of Hornblower's plan. For here, by the aid of the fly wheel, the moving piston is gradually brought (like the piston of the reciprocating engine) to a state of rest, so that the striking would be almost done away with. This being the case, we feel much difficulty in satisfying ourselves as to the cause of failure: and, but for the assurance that it did actually fail, we should have almost expected that it would have exceeded in effect any rotative engine we have yet described. For although there is reason to believe that the wadding or packing would be torn out of its place, in passing over the cavities for the admission and exit of the steam, yet that difficulty could be removed by the substitution of metallic packing, If this engine ever had a fair trial, under circumstances where there were no local inconveniences, we confess we cannot see why its effect was not *equal at least* to that of a beam engine. It is true, the revolution is neither continuous nor equable, but this is no more the case with any engine in use; but, on the contrary, a much greater mass of matter in others, that is to be brought to rest at each change of motion.

Mr. Samuel Clegg, of Manchester, obtained a patent for a Rotative Engine, in the year 1809, the principle of which is thus explained.

"Fig. 1. is the underside of a circular piece of cast iron, and of a diameter and thickness proportioned to the size of the engine. I is the common centre of the different circles shown on this piece. With any convenient radius, less than that of A A, describe the circle C C, and within the latter the circles D D and E E,—the radius of the latter being the least of those now named. From the uses of



(*Clegg's Rotary Engine.* 1809.)

these parts, which will be immediately described, an idea of their relative dimensions will readily be inferred. Let that part of the surface A B, A B which is contained between the circles A and C, be plain. Between the circles C and D sink a circular groove C D of any given depth; and between the circles D and E let another circular groove be cut, of the breadth D E, and of any given depth less than that of the groove C D. Let the remaining part of the surface A B, namely, that included between E and B, be cut down to any depth less than the depth of the groove D E.

"Into the groove C D, let such a number of segments of a circle be fitted as shall form a complete circle, excepting the space at L, which is occupied by adjusting screws or springs, to keep the segments close together. The segments are the breadth (or nearly) of the groove C D, and of a depth less than that of the groove C D. Those sides of them which apply to each other are to be ground together plain, and air-tight if possible. Their under sur-

faces, which are shown in fig. 1, are to be flat, so that the whole may form one complete plain surface, excepting the space before-mentioned, which is taken up by adjusting screws or springs L, which screws or springs are placed so far below the surface as to let a roller pass by them, which will be mentioned hereafter.

"Fig. 2. represents a vertical section of the plate and grooves of fig. 1, resting upon a circular chamber or hollow space Y Y, to which chamber the said plate forms a light covering, excepting that space occupied by springs or screws L L, as before-mentioned. I, the centre of all the grooves and circles before-described, is also the centre of the shaft. On the shaft I is fastened a plate or coupling Z, in which is inserted a bar F: this bar may be of any given breadth, but in depth must be less than that to which the circle E B was cut below the surface A B; to this bar is attached a wheel or roller G, shown in fig. 3, upon a larger scale. The manner in which it is attached to the bar F is also there seen, and it is so attached to it that the top of the wheel or roller G shall always be higher than the top of the bar F. The wheel G, being attached to the bar F, will, when the bar is made to revolve, describe a circular path H H H along the plain surface of the segments, before described. Let that portion of the plain surface of each segment which answers to the path of the roller G be rounded off, in such a manner as to make that portion of the surface an arc of a circle, the convex circumference of which is presented to the roller G. In fig. 3, at H, is shown a perpendicular view of one of the segments, rounded off in the manner described, and presenting its convex circumference to the roller G. There may, likewise, be another roller attached to the bar behind it, to lower down the segments in the same manner in which they are raised by the first roller. Now it is obvious, all the said segments being in their places in the groove C D, fig. 1, that the roller G, in performing a revolution round the centre I, must travel along a series of convex arcs of circles, equal in number to the number of segments in the groove C D. The groove D E is, in fact,

(*Clegg's Rotary Engine.* 1809.)

a recess in the deeper groove C D, and may, if necessary, be filled with hemp or tallow, or any other material which may answer the purpose intended.

"It must be remembered that fig. 1. is a view of the underside of the machinery. Fig. 2. is a section of it, supposed to be in its proper position, resting as a cover to the circular chamber Y Y, and the segments resting upon a flat facing OO. Each segment projects over the facing OO on both sides; their projection on one side completes the cover over the hollow chamber, and the other is the rounded surface for the roller to lift them. The facing OO is exactly, or as nearly as can be, level with the underside of the plate A B A B, when the plate is on its place, as represented in fig. 2; so that when the segments are all in their places, they complete the semi-circular chamber, and fit so close on their seats and in the groove, that were the chamber to be filled with any elastic fluid, they would prevent its escape, or nearly, excepting where the space is left for the springs or adjusting screws. The use of these segments, *which are what the patentee claims as his invention*, is as follows:—Conceive a door or valve to be fitted in the hollow chamber at Q, and a piston R, likewise fitted in the chamber so as to move round in it, and the bar F made fast to the piston, on the side and in the manner represented in fig. 1; then, if an elastic fluid of sufficient strength enters the chamber at N, it will press equally against the door or valve, and the piston; but the door or valve being immoveable, and the piston moveable, the piston will be propelled forward in the circular chamber by the elastic fluid. The bar F being fastened to the piston, and the roller G to the bar F, in the manner represented in fig. 3, and the roller being in motion with the bar and piston, the roller will lift the segments in succession, as it comes in contact with them. The segments before the bar being by this means lifted, allow the bar to pass, and the operation being the same in all, the bar and piston make a complete revolution. Each segment, as soon as the bar leaves it, falls down by its own gravity, or by springs, or any other contrivance, so that the opening which is made

for the bar to pass, is closed before the elastic fluid reaches it; the elastic fluid being kept from the opening by the inner breadth of the piston exceeding the outer diameter of each segment. The door or valve is lifted out of the way of the piston, when the piston comes in contact with it, into the opening in the plate at N, a recess being made in that segment which is opposite the door for that purpose; during which time the elastic fluid is shut out, but it enters again when the door returns to its seat, and thus the operation continues.

"In fig. 2, C is the condensing vessel, *a* the air pump, *b* the air-pump buckets, *d* the hot water cistern, *e* the clack. *ff*, the inclined plane for working the air-pump bucket, is fastened in the shaft, and consequently revolves with it. To the air-pump bucket is attached a hollow tube, through which the shaft goes. To this tube is fastened a cross bar, at each end of which is a roller *r*, resting upon the inclined plane: of course, when the plane revolves, the bucket rises and falls. The plane is divided into two different angles, so as to make it more acute where the bucket rises, but nearly an angle of 45° where the bucket descends, as represented in the drawing. The injection enters the groove above the blocks, and keeps about three inches of water upon them: the injection then enters the condenser out of the groove, as seen at X. Each segment or block, K, is of sufficient weight to resist the pressure against that part of their under surface which is over the semicircular chamber, and will generally be about five-eighths of an inch. The blocks may be likewise lifted exactly in their centre of gravity, by means of a lever in the upper part of the groove, and worked by a roller or small inclined plane fastened to the shaft, as represented by the dotted lines; and as it is not necessary for the blocks to rise more than half an inch or five-eighths, the motion will be very easy; and whatever descending power the blocks have, they will propel the bar forwards proportioned to their weight and the space through which they move, so that there is only the friction of the blocks to overcome. Supposing the pressure on the piston to be 800 lbs. the

weight of all the blocks will be about 500 lbs. for such a sized piston, and will seldom exceed more for the largest engines, as the space for the bar to pass will be nearly the same in all, the strength of the bar depending upon its breadth, not on its thickness: thus, 800 lbs. will move through the space of 16 feet, whilst 500 lbs. go through the space of half an inch; then, if the descending of the blocks be taken into consideration, as before described, the friction of the blocks will make no sensible difference to the progress of the piston. The lid M being the only opening into the engine, and the only stuffing box, and that covered with water, no air can enter but what is contained in the water used for injection."*

It is our opinion that this patent would never have existed, had Mr. Clegg been acquainted with the effects of steam acting on a lever, as explained at page 69. It is there shown that no increase of effect is gained by increasing the length of the lever; for although steam of a given pressure acts on a lever of two feet from the fulcrum with twice the effect it does on a lever of one foot, yet it is apparent that the consumption of steam is also double, and, therefore, that the power is as the steam consumed. Though it is presumed that this fact is too well known to need minute explanation, yet it is necessary now to mention it, since there can be little doubt but that if Mr. Clegg had been aware of it, he never would have made use of those segments which alone constitute his patent; the purpose of such segments being (as has been explained) to obtain the effect of the steam in a channel at some distance from the centre of motion, without making use of the interior cylinder or plate, used in most of such engines.

No advantage, therefore, arises from the use of these segments, but, on the contrary, the extreme nicety of their fitting is a considerable drawback; and we apprehend also, that they would soon become deranged, and suffer the steam to escape. But the most objectionable part is the valve, which has to be struck out of its place, whilst the pis-

* Specification of Patent.

ton is travelling at its full speed; indeed, there can be little doubt but that the rapid destruction of this valve was the cause of failure.

Mr. William Chapman's Rotary Engine, patented in 1810, is represented by the accompanying drawing.

(*Chapman's Rotary Engine.* 1810.)

A represents a drum, packed on its two enas, and revolving within an exterior cylinder C C, so that a channel is formed between the two cylinders, in which the steam acts upon the flaps F G. I is a cavity filled with hemp, which effectually stops up the passage or channel; an adjusting screw K tightens up the packing as it wears; D is the steam pipe, and E the escape pipe. The steam being introduced at D presses upon the valve or flap F, which recedes from the pressure, until the valve G having reached the roller H, is shut into the cavity L, and passes

under the stop I. As soon as it has cleared the stop, a pin on the outside strikes a lever attached to the spindle on which the flap is hung, opening it out again as before, so that it fills up the passage and receives the action of the steam, allowing F to be shut at the proper place, without interrupting the revolution of the axle. More explanation is unnecessary, as the drawing fully shows the plan.

An engine on this principle was tried at the iron works of Messrs. Hawks & Co. Gateshead, in the county of Durham; but so great was the noise made by the flaps striking the roller, that many of the workmen who heard it imagined the sounds to proceed from a tilt hammer. It was also found impossible to keep it steam-tight, by the greatest attention to the packing. Another engine of larger dimensions was also tried on the Tyne, but finally abandoned for the same reasons.

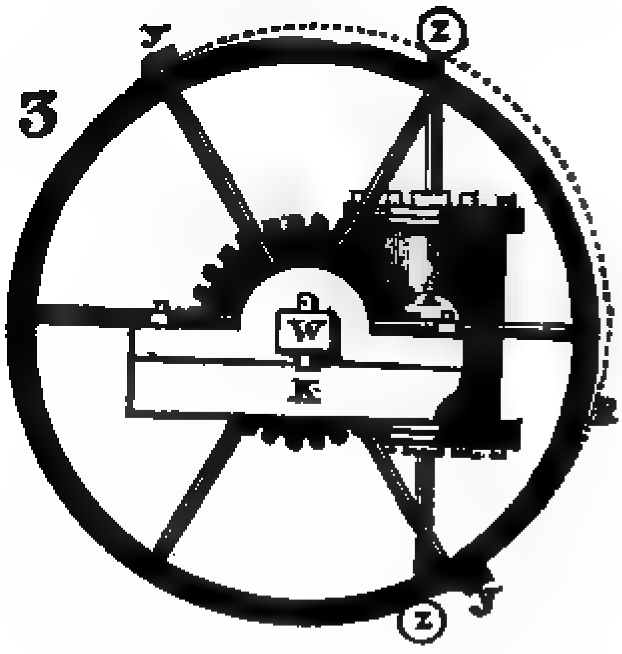
Mr. Richard Witty, of Hull, procured a patent, in 1810, for an engine, the revolution of which was effected by weights being alternately drawn to and driven from a centre, round which a working cylinder or cylinders revolved, there being attached to the piston rod or rods a number of weights. These weights were drawn as near as possible to the centre on the ascending side, and are projected outwards on the descending side, as far as possible from the axis.

In the following year, Mr. Witty took out a second patent for improvements on the former plan, which improvements consisted in making the piston draw or force round the machinery, whilst itself moved both in a rectilinear and rotary motion in a cylinder; which revolved upon an axis. The mechanical contrivances by which this was effected were of various kinds, which caused the power of the piston to draw or force the cylinder round. We here give those which we conceive to be most deserving of notice.

A, fig. 1, is the cylinder, shorter and wider than fixed cylinders, with its piston B, the rod of which works air-tight, through the stuffing boxes *a a*, at each end of the cylinder, with a provision at *w* to blow the air and water

at starting, when required. The axis or shaft, C C, is fastened at right angles to the cylinder, with screw bolts through flanch *i i*. In the axis are cast or bored two ducts or channels, *e f*, of sufficient capacity to admit steam to supply the cylinder. The ends of these ducts are securely plugged up. The side pipes, *h* and *g*, are joined to the sides of the axis, and communicate separately with the ducts, *e f*, in such a manner that the pipe *h* shall communicate with the duct *e*, and the pipe *g* with the duct *f*. The other ends of these pipes are joined to the ends of the cylinder. D D is the concentric collar, through which the taper part of the axis works air-tight; to this collar are screwed the steam pipe E, and eduction pipe F; the former leading from the boiler, and the latter to the condenser and the exhausting pump. The two holes in the collar, where the two pipes are joined, are made in the form of a parallelogram, so that when the cylinder, side pipes, and shaft, turn round through the collar D D, the communications betwixt the boiler and cylinder, and the cylinder and condenser, will be open alternately during half the revolution, and each side of the piston will be open, or exposed alternately to the steam and the condenser.

Fig. 2. represents what is called the cardioid motion, attached to the engine. It consists of a parallelogram, frame, or trammel groove, joined to the piston rod by the two triangles M M, M M. The two friction wheels, N N, are hung betwixt the ends of these triangles, and the piston-rod and rim betwixt the side joints *o o o o*, cast or screwed upon the covers of the cylinder. At the distance of half the stroke of the piston from the centre of the cylinder shaft is fixed a strong stud or pin, having a strong knee crank, at right angles from it, to support the gudgeon end of the cylinder shaft at S. On the round part of this stud runs a wheel P, filling the trammel groove, and the square is driven tight into another piece of cast-iron, and keyed fast, and this is bolted down to a beam of wood, as at K, fig. 3. When the steam is admitted under the piston, the trammel groove moves with the piston rod, and is



Richard Witty's Engine. 1811

turned from a rectilinear to a rotary direction by the stud P, resisting on one side of the trammel, and causes the cylinder to revolve towards the stud, and as it revolves the groove comes perpendicular, or at right angles, to the situation in which it is seen in the figure, the cylinder lies horizontally, the piston is at the extremity of its stroke, and the alternations of the steam take place at that instant in the axis. In this position, the engine may be said to be passing centres, similar to that of a beam engine, when passing the vertical position of the crank; and thus a continued revolving of the cylinder is effected, while its piston describes a circle, the diameter of which is half the length of the stroke.

Fig. 3. is a contrivance for applying the force of the piston upon a wheel R, or crank, which revolves upon a separate axis at W, placed half the length of the stroke of the piston from the centre of the cylinder shaft X, which is supported by a knee from or through the centre of the wheel, similar to the contrivance for supporting the gudgeon of the cylinder, fig. 2. The diameter of the wheel is made equal to the length of the piston rod; and has its rim made to incline or project, in order that the piston rod may lay hold of it alternately at the stops *y y*.

On inspecting the first invention, namely, the method of obtaining a revolving motion by the shifting of weights, it appears to us that Mr. Witty has quite mistaken the object which engineers have had in view, in their attempts to obtain a rotative engine. It will by this time be seen that the object was principally to avoid the waste of effect by giving motion to a mass of matter, and bringing it to rest at each movement of the piston of a steam engine. It will also be seen that these weights (the particular position of which constitutes the power of Mr. Witty's engine) have to be moved and brought into rest, exactly in the same manner as those parts of a steam engine whose motion causes the inconvenience complained of. The same objection, therefore, applies to his in a tenfold degree, for the common engine has only to overcome the inertia of such a quantity of material as may be necessary for suffi-

cient strength; but here, the whole power being obtained by the weights which are moved, the inconvenience sustained by reciprocation in engines of large powers will be readily conceived.

Mr. Witty's improved method, in which he dispenses with these weights, displays considerable ingenuity. It cannot, however, be properly called a rotative engine, because the steam does not act upon piston, vane, or any thing whose motion is rotative: his invention is merely a new way of applying the action of a common piston. The best mode, therefore, of appreciating its merit is by comparing it to a cranked engine, and in doing this we shall endeavour to show its inferiority.

The patentee states its advantages to consist in saving the power which is lost by reciprocation, and in dispensing with a fly wheel. To the first it may be said, that although the beam and some of its appendages are not necessary, yet the increase of the friction by the use of a grooved frame, and the danger of bending the piston rod by its oblique application in forcing round the engine, are greater inconveniences than those attendant on a beam; to which it may be added, that, when a crank is used, there are two points where the crank receives its impulse at right angles to the direction of the force, and is impelled in the same line with the piston, which is of course the most advantageous application of its power; but in no part of the revolution of this engine, in any of its modifications, does the impulse come much nearer the direction of the produced motion than an angle of 45°.

Nor do we think that a fly wheel can be dispensed with; it being quite evident that the different degrees in the obliquity of its direction must render a fly wheel absolutely necessary to produce an equable motion.

On this principle is the Revolving Engine of Mr. Samuel Morey, now used in several American steam boats. As there is considerable novelty in the mode of generating the steam, we apprehend its insertion will not be considered superfluous.

(*Mr. Samuel Morey's Engine.*)

a a a, are the steam boilers; *b b*, the tar vessels, to be afterwards described; *c*, the valve box; *d d*, the two revolving cylinders, shown in different positions; *e e*, the piston rods; *f*, the "pitman;" *h*, the centre piece; *i*, *i*, fixed supports for the frame; *k k*, the valves; *l l*, the steam pipes; *m m*, the escape pipes; *n n*, the condensers; *v v*, the face of the valves, shown in separate figures; *x*, the tar fire.

The frame, which holds the cylinders *d d*, is suspended by its opposite sides so as to revolve. The centre piece *h*, acting as a crank, is fixed to the end of *i*, projecting over

the cylinder, and from this centre piece the bar or pitma *f* communicates with the cross head of the piston rod Two circular pieces or valves *k*, one of brass and the other of iron, are placed on the bearance *i*, but on the outside of the frame; one of them being fixed to the axis, and the other accompanying the frame and cylinder in their revolution. From this last valve proceed the pipes *l l*, which conduct the steam to each end of the cylinder. The valve has a smooth face, which is kept close by springs to the face of the other valve, which is fixed to the shaft. The steam is conveyed from the boilers through the outer valve into the moving valve, and from the opposite side of the outer valve proceed the eduction pipes, which lead to the condensers.

These condensers are upright vessels, two of which belong to each cylinder; they are connected at top by a sliding valve box, by which the steam is made to enter them alternately. They have two valves at the bottom, which are kept closed by weights. A stream of water is injected into the condensers, which escapes by the bottom valves *p p*, by which, also, the air is blown out at every stroke; in this manner the engine is at first cleared of air.

In order to give a reversed motion to the engine, two cocks and cross pipes are employed, for the purpose of changing the passage of the steam to the opposite sides of the valves.

When the engine is thus constructed, the steam admitted below the piston by the lower pipe *l*, forces up the piston rod *e*, and the cross head at its upper extremity. This cross head, carrying along with it the bar *f*, acts upon the crank *h*, which thus gives a rotatory motion to the shaft 1. 1., and of course to the cylinders and frames; the shaft 1. 1. by means of a pinion 2. 2. drives the paddle wheel.

With the view of saving fuel, this engine has the *Gas Fire* applied to it in the following manner:—The boilers are cylindrical, with an inside flue for fuel, two or three are placed closely together, and set in the following manner; first, cross bars of iron are laid on the timbers; a platform of sheet iron is laid on these bars, coated over

with clay, mortar, or cement, to keep out the air. Upon the sheet iron, and over the bars below, are placed cast iron blocks, in shape to fit the curve of the boiler, so as to raise it three or four inches above the platform. The sheet iron is continued up the outsides of the outer boilers so as to enclose them; and at one end, between the boilers, there are small grates for coal or other fuel.

The tar vessel or vessels are lodged in the space between, and upon the boilers, and a small fire may be made under them, if necessary. A pipe leads steam in at one end, two pipes at the other; one near the bottom, one near the top, lead out the tar and steam. These pipes unite below; the steam and tar thus mingled, in suitable proportions, flow to the plain fire, or the flues of the boilers, as well as to the coal fire below, where the gas and tar are ignited. The fireman judges of the proportions of each by the effect; the object being to produce a nearly white flame, without appearance of tar. Thus flame is applied to the greatest possible surface, and the apparatus adds very little cost to the engine.

Mr. Morey has also made two other improvements in the boiler. The first of these consists in lining or covering the flue within with sheet iron or copper, perforated with small holes, reaching down its sides nearly to the bottom. By this contrivance the water is made to circulate rapidly between the flue and the lining, up to the top of the flue, and thus protects it from being run dry, or heated red hot, when the water gets by accident too low. In consequence of this circulation, the lining causes the steam to form much faster.

The other improvement consists in an interior boiler or vessel, occupying the back part of the flue, and communicating downwards with the water, and upwards.

Several engines of Mr. Morey's construction have been erected. The Hartford steam boat, 77 feet long, 21 feet wide, and 136 tons, is propelled by one of them. In this vessel, the engine with its boiler occupies a space of 16 feet by 12, or one eighth part only of the boat; the cylinders being hung in the timbers of the deck, over the

boilers. The two cylinders are 17 inches each in diameter, and have a stroke of 18 inches, and revolve 50 times in a minute. The area of the piston being about 227 inches, it will, when worked with steam of 50lbs. have the power of 100 horses.

The Rotative Engine of Mr. Onions, of Bristol, patented 1812, differs essentially from all we have described. The invention consists of an annulus or hollow ring connected by hollow arms, with a revolving shaft also hollow. The steam is admitted at one end of this shaft, passes through one of the arms, and thereby gets into the rim, in which are valves so placed as to prevent the steam from acting in more than one direction. The annulus is nearly half filled with a metallic alloy, composed of eight parts of bismuth, five of lead, and one of quicksilver. The property of this alloy is, that, although solid at the common temperature of the atmosphere, it becomes fluid in boiling water or steam. The steam, therefore, when introduced into the wheel, after first fusing the alloy, forces it up on one side of the wheel, thereby making it heavier than the other: the metal, in attempting to regain its equilibrium, causes the wheel to revolve; and the supply of steam being continued, the revolution is kept up. For a more perfect comprehension of this machine, our readers may inspect the drawing we have given of Watt's Rotative Engine, at page 74, where the operation of the valves, and entrance and escape of the steam, are effected in a somewhat similar manner. The machines in fact will be nearly the same, if we suppose Mr. Watt's weight to be a fluid instead of a solid one.

A singular mishap befel this machine on its first trial. It is a property of bismuth that, like water, it expands as it crystallizes or becomes solid, so that, on the morning succeeding its trial, the engine was found broken or rather burst into small fragments, owing to the expansion of the alloy. This result, therefore, proved that, in order to preserve the engine, it was necessary either to keep it constantly hot, or to remove the metal before it became solid: either of which would be a sufficient objection to its

adoption. But there are besides, other difficulties to contend with in this kind of engine, which we shall notice in our remarks on Masterman's steam wheel.

In Mr. Trevithick's patent of 1815 is introduced a column or ring of water, which running round the piston renders the whole air-tight. By this means he avoids a great proportion of the usual friction, a very moderate degree of tightness in the packing being in practice found sufficient to prevent the passage of so dense a fluid as water. The second part of this invention consists in causing steam of a high temperature to spout out against the atmosphere, and by its recoiling force to produce a motion in a direction contrary to the issuing stream, similar to the motion produced in a rocket wheel, or to the recoil of a gun, by which means a rotative action is produced. Mr. Trevithick also describes three other improvements on the high-pressure engine, the latter of which, though only applied to nautical purposes, is by far the most important. It consists in employing a spiral worm or screw, similar to the vanes of a smoke-jack, which being made to revolve at the head or stern of the vessel, produces the required motion.

Mr. Turner's Rotary Engine, patented in 1816, displays extraordinary ingenuity and excellence; we therefore give from the specification a more enlarged account of it than of most other such inventions.

"Fig. 1. is a plan of the engine, represented as if opened to show the internal structure. Fig. 2. is another plan. Figs. 3. and 4. are sections, taken through the axis of the engine in different directions, to show the internal parts. A A, B B, C C, is the cylinder, or external case of the engine, made in two or more parts, which are fastened together with screws, so as to form a circular or annular passage, the transverse section of which is likewise circular, as shown at E E, figs. 3. and 4.; the piston F, fig. 1., is accurately fitted into this circular passage, and is caused to revolve therein by the pressure of the steam, which is applied behind it or on the side F, whilst a vacuum is made before it, or on the side G. The piston being connected with a central plate G, which is fixed fast upon the axis

(Turner's Rotary Engine. 1816.)

(Turner's Rotary Engine. 1816.)

or shaft H, the said shaft is put in motion, and by wheel work I, or other machinery which is best adapted, the power of the engine is communicated to any useful purposes to which it is intended to be applied. The means by which the force of steam is made to produce the rotatory motion is as follows: two valves or sliders, K and L, are applied at the opposite sides of the annular passage or cylinder, E E, in the manner represented in figs. 1. and 3. The edge of the central plate G, which has the projecting arm to communicate with the piston, must be made so that they can be made to shut up the passage of the cylinder, E E, as represented at L, and prevent the passage of the steam

through the same, or the slider may be opened, as shown by the dotted lines, to allow the piston F to pass freely through the cylinder; this is done by moving it sideways on its centre 3, out of the cylinder into the box or case M, which is provided for its reception. The sliders are put in motion by a communication from the outside of the engine, so that each one shall begin to open as soon as the piston F approaches it, and shall be completely opened whilst the piston passes by, and that it shall then descend again upon its seat. N O, figs. 1. and 4., are two passages, through each of which the steam is alternately introduced and withdrawn from the cylinder; the two passages are placed on opposite sides of the centre of the engine, and are provided with valves or cocks, which are adapted to be opened and shut by the action of the machinery in such succession, that when steam is entered from the boiler, into the cylinder at one passage, it shall be going out into the open air, or to the condenser at the opposite passage. The machinery which actuates the slides K L, and the machinery which opens the valves for the admission and exhaustion of the steam through the passages N and O, act in concert with each other, and also with the motion of the piston F; so that, as soon as possible after the piston has passed by the seat of a slider, the same shall be lowered down into its place, ready to close the passage of the cylinder behind the piston, and the instant the piston has passed by the next opening, the steam is admitted to flow therein, and act between the slider and the piston, to force the same forwards in the cylinder by its expansive force.

"To explain the action of the engine more clearly, suppose the parts in the position of fig. 1.; the slider L is shut, and the steam is flowing through the passage O into the space between the slider L and the piston F, at the same time the passage N is open to the condenser, to exhaust the steam from the remaining part of the cylinder, and remove the pressure from the front side G of the piston. In consequence, the pressure of the steam acting behind the piston of the side F, puts the same in motion in the direction of the arrow, and drives the arm of the central plate be-

fore it. The slider K, now in the act of opening, and by the time the projecting part of the plate G arrives at its seat, it will be quite open into the box M, where it will remain until the piston F has passed by its seat; it then begins to descend, and by the time the piston arrives at the opening of the passage N, the slider K will be completely shut, and stop the cylinder. The instant the piston has passed over the opening of the passage N, the steam valves are changed by the machinery, so as to admit the steam into the passage N, and also to allow the steam to pass away through the other passage O to the condenser; in consequence, the steam enters the space between N and K, and thus, being behind the piston, drives it still forwards towards the slider L, which immediately begins to rise by the action of the machinery, and as soon as the projecting part G of the central plate approaches it, it will have retreated into the box M, leaving the cylinder free for the passage of the piston. Immediately after the piston has passed the slider, L descends again, and gets settled to its place by the time the piston arrives at the opening O; and the instant the piston has passed over this opening, the steam valves are changed again, so that the steam will be admitted at O behind the piston, and act between the slider L and the back of the piston to force it forwards, which is the same position represented in the figure. By this means the pressure of the steam is always made to act behind the piston, and the vacuum is made before the same. The sliders K and L are put in motion by levers 9 and 10, which are fitted on the outsides of the boxes M, but move upon the same centre pins 3, as the sliders move upon withinside the boxes, the levers being forked, as shown at fig. 5, to reach on each side of the boxes, and the centre pins 3, pass through the sides of the boxes, and also through both forks of the levers 9, 10, but do not turn round in the holes. To communicate motion from the levers at the outsides of the boxes to the valves withinside, curved rods, 11, 11, are carried from the levers through the sides of the boxes M, and jointed to the arm of the sliders; stuffing boxes are formed round the rods to

make tight fittings where they pass through the sides of the boxes M; the ends of the levers, 9, 10, are made to be included in an eccentric groove or rein Z Y, fixed to the central axis H; the form of this is shown in fig. 2, and is such as to hold the sliders shut, except during the time that it is necessary to lift up the same to allow the piston to pass by. To make the sliders fit steam-tight when they are shut, they are made rather larger than the diameter of the cylinder, and are received in grooves made round in the inside thereof, and the valves are ground against one of these faces of each of these grooves, so that they will fit tight without any packing. The piston is made of several segments put together, with springs behind them, to throw them out against the inside surface of the cylinder, and it is thus made tight without any packing of hemp.

"The edge of the central plate G, which has the projecting arm to communicate with the piston, must be made to fit tight between the upper and lower halves which compose the cylinder, so as to prevent the escape of steam between them, and at the same time leaving the said plate freely at liberty to revolve in the space; for this purpose the edge of the plate is surrounded by two rings of brass, 5 and 6, which are laid one upon the other with springs between them, so as to throw them against the upper and lower surfaces of the central space, to which they are accurately fitted by grinding; these rings extend round rather more than half the circumference of the plate G, and are attached thereto by a joint-pin 7, fig. 1, which causes them to revolve with it; but they require no other fastening, as the pressure of the steam will keep them in their places.

"To prevent the escape of the steam through the opening or division between the two rings 5 and 6, a third ring, 7, 8, fitted to them, covers the joints, and the external edge of this, which is made round or semi-circular like a bead, is received into corresponding notches made in the edges of the sliders, and thus to make a fitting between the edges of the sliders, when the same are closed, and the edge of the moveable central plate. The valves which are

to admit alternately the steam into the passage N O, may be constructed in the same manner as the valves for the ultimate supply of the upper and lower part of the cylinder of any common steam engine; but the most convenient manner of doing this is shown in fig. 4. Q Q, is an iron box, into which the steam from the boiler is admitted: this box is fixed beneath the cylinder of the engine; 17, 18, are two openings from which curved tubes proceed upwards to the openings, N O, of the cylinder; there are also two other openings, 19 and 20, which turn downwards with crooked tubes to the condenser S. T V are boxes or cups fixed at the opposite ends of a lever T W V, of which W is the centre of motion; the boxes or cups are intended to cover the openings, in the manner represented by the figure, and the faces or edges of the boxes are ground to fit close upon the flate plate or surface, in which the openings 17 and 18 are made. When the box T is up, as in the figure, it covers the two openings, 17 and 19, so as to connect them together, and therefore the steam in the cylinder will be drawn off through 17 and 19 to the condenser; at the same time the box V at the opposite end of the lever is drawn, and in this position the box leaves the opening 18 uncovered, so that the steam with which the box is filled will have free passage into the cylinder; by moving the lever T V on its centre W, sufficiently to raise up the box V, and depress the other T, the action will be exactly reversed, *viz.* the box V will connect the openings 18, leading from the cylinder, at the opening 20, which leads to the condenser; and the opening 17, will be uncovered, so as to admit the steam from the box through it into the cylinder at the opening N."

There is great ingenuity displayed in the formation of this machine, and the whole shows much mechanical ability; nevertheless there are defects of a sufficiently prominent nature to account for its failure. The very common fault of great friction, arising from the use of the revolving plates, is here a difficulty which we conceive could not be readily overcome; but the principal cause would be leakage, arising from the impossibility of keeping the rub-

bing surfaces steam-tight. This leakage would take place principally in the part where the sliders should be in contact with the central plate; it appears to us that the rapid motion of the slider must necessarily cause it to rebound from the plate, and leave an open space for the escape of the steam; we also apprehend that the surfaces of each slider would in a short time become so irregularly worn, that it would not fit its seat on the surface of the groove, for the top and bottom of the slider are constantly in contact with the surface of the groove, during the whole of its motion, whilst the sides (speaking relatively, for there can be neither tops nor sides of a circle) are merely in contact at the time the slider is moving through a space equal to the depth of the groove. This will produce a greater wear on one part of the slider than another, and of course, in time, cause the joint to allow an escape of steam.

Another fault in this machine is, that the mode of working the sliders by means of the semi-circular rods is a very insecure method; and from the indirect application of the power necessary to work them, there is a constant danger of bending the rods, and, consequently, leaving the slider in the groove. If this were to happen, the piston in its revolution would come violently in contact with the slider, and most likely cut it in two, or otherwise injure it and the rest of the engine beyond repair.*

A patent was obtained by Mr. Joshua Routledge, of Bolton-le-Moor, in the year 1818, for a Rotary Engine, of which the accompanying drawing is a section, and may be thus explained.

Suppose the steam-stop C, and the lever H *b*, to be properly packed in the situation represented by the drawing, so that the steam cannot escape past either one or the other, it will be evident that if the steam be admitted through the pipe G into the space M, the lever H *b* will be

* The author of Stuart's History of the Steam Engine states—"that the general arrangement of the parts and manner of action of this engine resembles Mr. Mead's." This apology for omitting the ingenious apparatus of Mr. Mead is singular enough, as no two machines which we have described can be more essentially different.

(Routledge's Rotary Engine 1818.*)*

propelled forward towards C, through the space Q, until the sloping part H comes in contact with the lower point of the steam stop C, which will then turn upon a steam-tight joint or centre O, and rise up into the box or chamber D, until the lever H *b* has passed by. The pressure of the steam then compels the stop C to follow the lever down the inclined plane *b*, until it comes into its former resting place, where it remains stationary upon the cylindrical part of the lever, as seen in the drawing, until again raised by the sloping part H as before. During the time that the point H *b* is passing the steam-top C, the steam that had last carried the lever round makes its escape through the pipe B, either into the open air or into a condenser, and new steam is again instantly admitted, and so on continually. When the engine is thus constructed with only one arm or lever, there is about one-tenth of the circle or revolution where the steam has no power; the motion of the engine is then kept up by the velocity

already given to the fly wheel; but when two arms or levers are used, as in large engines, then the steam is made to act with equal force through the whole of the revolution.

A patent was obtained, in the year 1818, for a Rotary Engine, by Mr. John Malam, of Westminster, which in its general principle resembles those of Messrs. Cartwright, Chapman, and Routledge; the details, however, are somewhat different. The main point of difference is, that Mr. Malam purposes to cause his external cylinder to revolve, and leave the interior one at rest. This he purposes to effect by using a "leaden piston," which by its weight will always remain at or near the lowest part of the circle, whilst the steam acts upon valves or flaps which, after they pass the piston, open out and receive the action of the steam. There are three of such valves, which are exactly the same as those used in the engines of the persons just mentioned, and operate in the same way. The piston consists of a heavy block of lead, fitted exactly by packing or otherwise to the cylinder; and the whole apparatus differs so little in other respects from those, that it is apprehended no further description will be necessary. The motive of the patentee, in causing the external cylinder to revolve, was evidently to avoid the inequality of wear which may arise from fixing the external cylinder, and making the internal parts to revolve; for, in the latter method, the axis and machinery attached to it have a tendency to wear downwards by gravitation, and get out of truth; this would in time cause the cylinder to assume an oval form, and thereby render it difficult to be kept tight by packing, and this (it should be observed by the way) has been considered as one objection among the many urged against rotary engines, though perhaps, if every other could be overcome, this, on account of the length of time which must elapse before it could occasion a serious inconvenience, would not operate to prevent the successful application of such an engine.

But it must appear to all, that the patentee's plan of obviating this evil is but a clumsy and ill-contrived one.

The valves out of the question (the faults of which have been already explained), we cannot for a moment think that the weight or piston could afford an abutment of sufficient firmness and steadiness to produce any regular and equable motion; indeed, we doubt whether any weight, placed as this was, could remain stationary whilst passing over the inequalities of such a cylinder, and enduring the varied force of the steam upon the changing of the valves. There can be little doubt but that it would vibrate to and fro, as each valve opened and shut, and thereby destroy as much power by reciprocation as any steam engine ever known.

The same specification likewise contains a description of another rotary engine, in which the abutment consists of mercury, water, or fusible metal, such as lead and bismuth. In this engine there are three drums, the exterior one forms a casing or jacket to the second, and is kept heated by steam or hot air. These two outer drums are stationary, whilst the inner one revolves upon its axis, one end of which is tubular, for the admission of the steam. There are attached to the moving cylinder certain curved partitions, which form chambers something like the buckets of a water-wheel. The steam being introduced through the hollow axle, after filling the inner cylinder, flows into one of the compartments formed by the curved partition, and pressing upon the fluid, causes the drum to rise on that side and revolve upon its axle; this suffers the steam to enter the compartment underneath the first, (in a manner not clearly described), and force it out of the fluid. The first compartment is by this time above the level of the fluid, and the steam at liberty to escape into the channel above, which communicates with a condenser or the open air. The chambers are thus filled with steam, and raised in succession above the surface of the fluid, and produce a constant rotation of the axis.

This latter scheme differs little from the Steam Wheel of Sir W. Congreve, which is simply an overshot wheel completely immersed in some liquid, in which it is made to revolve by the introduction of steam underneath the in-

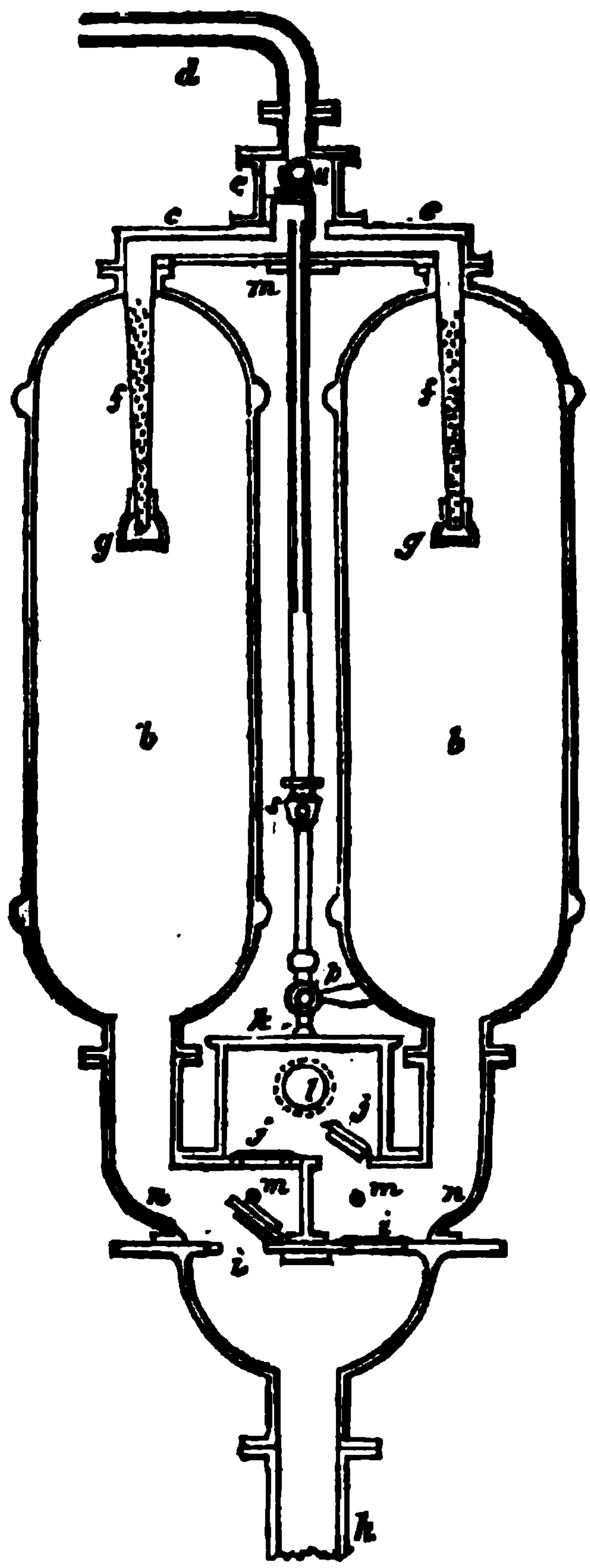
verted buckets, which by displacing the water with which they are filled, renders one side of the wheel buoyant, and causes it to ascend. By this means the buckets are successively brought above the induction pipe and filled with steam, which continues the buoyancy of the ascending side, and keeps up a constant revolution of the axis. The steam in the buckets is discharged into the air as soon as they have reached the surface of the fluid, the latter then entering them and occupying the place of the steam.

Neither of these schemes is sufficiently meritorious to demand much consideration, and they only deserve notice because they have engaged the attention of highly-talented individuals. Mr. Bryan Donkin and Mr. Malam have both tried the same plan, and found that the effect bore a very small proportion to the steam expended. This was mainly attributed, in the water engine, to the large quantity of exposed liquid which is to be maintained at a temperature equal to that of the steam, and to the difficulty of getting the steam into the buckets without allowing a considerable portion of it to escape through the water, without at all aiding the revolution of the wheel. An insuperable difficulty also was encountered regarding the temperature of the water; for if the water were below the boiling point, a great portion of the steam was condensed, and if at or above that temperature, the water was speedily dissipated in vapour, and required to be replenished by more water, which, if not sufficiently hot, again produced condensation, but if it were used boiling hot, a separate boiler was necessary to supply the reservoir.

Any one of these difficulties, however, we apprehend would be sufficient to prevent success, and this may account for the failure of the mercury engine of Mr. Malam, in which it appears that the great evil would be the steam wasted, by escaping past the sides of the compartments; for without the nicest regulation of the supply of the steam, not one half of it would take its place in the bucket, owing to the facility with which it might displace the mercury and rush through it to the surface, and so to the eduction pipe. We are not able to speak as to the oxidization

which would take place on the mercury, when exposed to constant heat, but we apprehend this would be very considerable, and of course add to the defects of the plan.

We described in a former part of this work a very simple modification of Savery's plan of raising water in the engine of Mr. Nuncarrow; and from the great simplicity of another apparatus, on the like principle, we are induced to give an account of it. We allude to the machine of Mr. Pontifex, of Shoe Lane, London, whose improvement consists, it will be seen, in rendering the machine a self-acting one; but, besides this, the skilful arrangement of the parts, and the precision and certainty of its movements, make it an object worthy of attention.



(Pontifex's Water-raising Engine.)

"*b b* are two steam cylinders connected by cross tubes at *c c*, in each of which a vacuum is alternately formed by the condensation of elastic vapour, connected from the boiler by the bent tube *d*, and admitted to the steam cylinders by means of the sliding valve, *e*. *f f*, two tubes perforated with small holes for the admission of steam and injection water, the latter of which is distributed by falling on the strap, *g*. *h*, the suction pipe, proceeding to the bottom of the well, which in no case ought to exceed from twenty-eight to thirty feet in depth; so that a vacuum being formed in the copper vessels, *b b*, the water will be raised by the pressure of the atmosphere, and passing up the tube *h*, will take the place of the elastic vapour. *i i*, two valves placed at the upper end of the suction pipe, *h*, which allow of the upper passage of the water from the well, but prevent its return. *j j*, two similar valves, opening into the air vessel, *k*, to which is attached the nozzle *l*, serving to convey the water from the copper vessels to any required point. *m*, the injection tube, furnished with a valve, and intended to convey water from the box, *n*, to the taper tubes, *f f*. *p*, stop cock to regulate the supply of condensing water. There is a tube passing from the bottom of the cistern, *n*, to the injection tube, *m*, and furnished with a stop-cock at *s*. To put this engine in action, the steam must be first raised to the boiling point, and the valve or cock opened, which admits it to pass from the boiler to the pipe *d*. One of the buckets must now be made to descend, which will open the sliding valve, *e*, and admit the steam into the cylinder, *b* 1. The atmospheric air, which will thus be expelled from the cylinder, is allowed to pass through the valve *j*, and nozzle *l*. The other bucket must then be depressed, and by its action upon the sliding valve it will open a communication for the injection water through the pipe, *q q*, which passing down the perforated tube, *f*, will immediately condense the steam, and form a vacuum in the vessel. The whole pressure of the atmosphere being now removed from the suction pipe, *h*, the water will rush up to restore the equilibrium, and the vessel, *b*, being filled, will furnish a supply at the bent tube, *l*.

"Having examined the action on one half of the apparatus, we may suppose the same effect to be produced on the opposite side. The steam will, in the first instance, be admitted by the pipe *c*, and a communication afterwards opened by means of the sliding valve with the condensing water, which by reducing the steam to its original bulk, will form a vacuum, and the water will again ascend as in the first vessel. The stop-cock, *y*, must now be opened, and the bucket *x*, (first described) made to descend, which will remove the sliding valve, *e*, to its original position, and admit the steam to the upper part of the first vessel, which will depress the water and cause it to flow through the valve *j*, and nozzle *l*, while at the same time the water will pass through the tube *u u*, in which the valve *w*, is inserted, beneath the inverted vessel, *v*. The water will continue to enter the bucket, *x*, till its increasing weight causes it to preponderate, and turn the sliding valve, *e*, in the opposite direction. Should there not be a sufficient supply of water in the cistern, *r r*, for the purpose of condensing the steam in the larger vessels, the stop-cock, *p*, must be opened, and an additional supply of water will then be furnished from the chambers, *n n*, by the tube *m*; and in the event of the bucket not being depressed at the instant that the water is expelled from the chamber, *n*, of the vessel *b*, the steam will pass through the tube, *u u*, and act between the under side of the fixed inverted vessel, *v*, and the surface of the water in the moveable bucket, *x*, the descent of the bucket being accelerated by the repellent force of the steam, so that by the alternate action of the buckets, *x x*, the motion of the engine is rendered continuous.

"It appears that each steam vessel in the engine employed at the City Gas Works, contains about 36 gallons of water, which is raised by each about 28 feet, three times every two minutes; one bushel of coals, or two of coke, serving the boiler about two hours and three quarters."*

In 1821, a patent was obtained by Mr. Job Rider, of

* Partington's History of the Steam Engine.

Belfast, in Ireland, for a rotary engine, which has been the subject of great encomium in several periodicals of the day, some of which have not hesitated to declare, that in it was to be found the solution of the grand problem hitherto sought after in vain. But although we have been favoured with some very diffuse remarks by these works, all of them have omitted to notice the fact of its being nearly a fac-simile of a machine patented by Messrs. Bramah and Dickenson, thirty-one years previously to this date. We do not mean to declare that Mr. Rider is not the inventor of this machine, because although a minute description and engraving of it are given in one of the early volumes of the Repertory of the Arts, yet we well know that this work is too scarce to be found in the hands of every inventive mechanic: besides which, it is highly improbable that Mr. Rider would have incurred the expense of a patent or patents for a machine which was notoriously the subject of a previous one. It is, however, to be regretted that Mr. Rider was not better informed on the subject, because the two plans resemble each other so closely, that one might almost fancy they had been drawn from the same model. We refer our readers, for a full explanation of the principle, to page 107, of this work, and have merely to add, that a respectable manufactory in Scotland expended a very considerable sum in constructing and applying one of these engines during the year 1825, but have abandoned it, from the impossibility of keeping it even tolerably steam-tight.

Mr. Thomas Masterman's rotatory engine, patented in 1821, which is the same species of engine as Mr. Onions's, already described, comes next under our notice.

Fig. 1. represents a vertical and central section of the troke (being that part of the engine which revolves). Fig. 2. is a transverse section of it, and of the two masks after-mentioned. The troke is composed of the axis, of the nucleus (being the central parts, and through which the axis passes), of the annulus (being a hollow ring, in which are placed valves), and of the radii (being the steam passages between the nucleus and the annulus). The sur-

face of the face is a perfect plane. The axis passes through the hole (1) at right angles with the plane of the face. Six holes (2) of similar figure and dimensions with each other, are sunk in the face, at equal distances, in a direction parallel to the axis, for three or four inches; then curving into a direction at right angles with the axis, they open in the periphery of the nucleus.

The annulus (A) consists of six equal segments. At each of their joints is fixed a valve, which, by being ground on its seat, is rendered steam-tight when closed.

The radii (1, 2, 3, 4, 5, 6,) are connected with the nucleus and annulus, so as to form steam-tight communications between each hole in the face and the inside of the annulus. Fig. 3 is a plan of the inner mask; being a circular plate of metal, of equal diameter with the face, about two inches thick, and having each side perfect planes parallel to each other.

There are four holes (1, 2, 3, 4,) through it: 1 is of sufficient size to admit the axis; 2, 3, 4, are each one sixth of the space that would be included by completing the two concentric circles, segments of which form the sides of those holes; and those circles are described with the same radii as the segments of those which bound the holes in the face. Thus, each of these holes would extend over one of the holes in the face, and one of the adjoining spaces: the space between 2 and 3 is of such dimensions as just to cover completely one of the holes in the face. 4 is situated so as to leave equal spaces between it and 2 and 3.

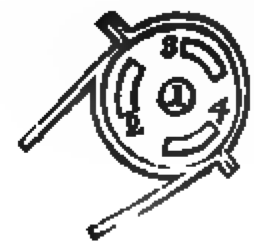
The periphery of this mask is clasped by an iron hoop, from which projects a lever, extending nearly to the annulus, and having a small inclined bar placed across its end. The two projections from fig. 4. represent the beginning of the lever.

The outer mask is a circular piece of metal, of the same diameter, and about the same thickness as the inner mask.

The axis passes through both masks; the inner mask is placed next the face, the other next the inner mask, and both are kept closely pressed towards the face (by means of screws acting on the back of the outer mask), so as to be

MASTERMAN'S STEAM WHEEL.

Fig. 3.



(*Masterman's Rotary Engine.* 1821.)

steam-tight with each other and with the face: a trifling pressure suffices to make them so, the opposed surfaces having been ground on each other. The outer mask is placed in such a position with respect to fig. 1, as that the pipe, 2, may be horizontal, and point towards radius, fig. 2, and it always remains stationary. The inner mask is placed in such a position with respect to the outer mask, as that the holes 2, 3, 4, in the former may communicate with pipes corresponding in the latter, and thus form a communication between the pipes communicating with the boiler and the air. Thus the holes in the inner mask are for the same relative purpose as the pipes in the outer mask.

The transverse sections of both masks, placed in their relative positions, are represented in fig. 2.

The corresponding letters in fig. 1 and 2, refer to the corresponding parts in each: *p p* are the axis, *g g* are its bearings.

As the valves, and the gear for regulating them, are precisely the same in each segment of the annulus, only two of them (one showing their position closed, the other open) are lettered for reference.

Each valve (*f*) is similar to the other, and opens in the same direction; its gudgeons, moving freely in sockets, fixed to the sides of the annulus nearest the axis.

Their working-gear is as follows: *a* is a small hollow protuberance or bonnet screwed on the annulus, and communicating with the inside of it; on one of its inner sides is a socket, on the opposite a stuffing-box; one end of a spindle works in the socket, the other passes through the stuffing-box to the outside of the bonnet; to this end is attached the lever *b*, and to the centre is attached the lever *c*; both levers being at right angles with the spindle, and in the opposite direction to each other. To the extremity of *c* is attached (by a moveable joint) the rod *d*, and to the extremity *b* is fixed the weight *e*, being more than sufficient to counterpoise *f*, which is connected with it by means of a moveable joint at the other end of *d*, and attached to the centre of *f*. The levers are so placed as to cause *f* to be half open when they point to the axis. Thus

it is evident that, during the revolutions of the troke, two of the valves (*f*) on its ascending side (denoted by the arrow) will, by the mere preponderance of *e*, be shut, and the whole of the others will be open, as represented in fig. 1.

For more easily comprehending the action of these valves, let it be considered that their movements are regulated by the mere gravity of the weight *e*.

The machinery to which motion is to be imparted is attached to that end of the axis next fig. 1.

The steam is generated and condensed in the usual manner.

The principle on which the engine acts, is by a liquid body (water or mercury, for instance) placed in the annulus, being pressed on one side of the troke by the steam, until that side gains such a preponderance over the other, as to overcome the resistance of the machinery attached to the axis, and by being then sustained there, to maintain the preponderance during the revolution of the troke.

The engine represented by the engraving is one in which water is the liquid made use of in the annulus. The manner in which it is worked is as follows:—

The annulus is nearly half filled with water, which need never be withdrawn. The troke is placed so as to have two of its radii in a vertical position. The steam-cock is turned; consequently the steam rushes through the pipe and hole (2) in the outer and inner masks, and through the lowest hole in the face into the lowest radius; and, after imparting to the surface of the water in that radius its own temperature, it presses such water downwards, and flows into the annulus, condensing in the water therein, until it has imparted to it, also, its own temperature, which will be rapidly accomplished. On the temperatures becoming alike, the steam will rise through the water on both sides of the troke, and, meeting with a closed valve on one side, will press the water which is beneath it downwards, and consequently cause the water on the other side to rise proportionably, until the preponderance thus given to that side, be sufficient to overcome the resistance of the

machinery attacned to the axis, whereupon the troke will immediately begin to revolve. The load, or resistance of the machinery, remaining the same, and the supply of steam being equable, the water will remain nearly stationary during the revolutions of the troke: its surfaces are denoted by the lines at *n* and *o*.

As the troke revolves, each of the holes in the face communicates in succession with 2, in the inner mask.

It should be borne in mind, that, as has before been observed, the position of the inner mask is never so far changed as to prevent 2 and 3 therein communicating with the corresponding pipes in the outer mask, when the engine is at work.

By the construction, one entire hole in the face, or parts of two, equal to one, is, or are always in communication with 2 in the inner and outer masks; so that there is always an equable flow of steam into the annulus, preventing the depressed surface of the water rising with the ascending closed valve.

The holes in the face, as they pass in succession from 2 to 3 in the inner mask, are entirely closed by the space between them; and immediately on communicating with 3, the steam confined between the two closed valves rushes from the annulus, through 3, into the air, or into the condenser, if one be used. And until the same hole in the face has passed 3, a communication with the air, or the condenser, remains for the discharge of the steam.

The pressure of the steam being thus removed from each valve, (*f*) as it arrives at this point, it will, by the gravity of *e*, open as it begins to descend, (see the valve partly open in fig. 1) and thus allow the column of water to remain on that side of the troke.

The water will fill the radii as their ends descend beneath the elevated surface, *o*, and will remain there until the steam presses it out at about *n*, but cannot escape, if before it enters them the hole in the face has pressed the hole 3; otherwise, however, the water would escape through that hole into the air, or condenser.

A uniform rotatory motion is thus produced and main-

tained as long as the steam flows equably into the annulus, acting with a force proportionable to the preponderance of the water on one side of the troke over the other. This force is easily estimated, being equal to the weight of a perpendicular column of water, having the difference of the two levels for its altitude, and the area of a transverse section of the annulus for its base, pressing against the closed valve.

This description of Mr. Masterman's engine is copied from a pamphlet published by Messrs. Underwood in 1822, which gives a very clear description of the whole machine, together with a detail of the comparative advantages the writer imagined this machine to possess over the reciprocating one. As it will serve our purpose best, in treating on this machine, to follow the author through some of his remarks, we will step out of our usual course in the present instance.

The difficulties which are stated to have been obviated or lessened by the invention of this engine are, "1st, the skill and nicety of workmanship required in construction and erection; 2d, the cost of construction and erection; 3d, the space they occupy; 4th, the expense of working and keeping them in repair; 5th, the power lost by friction, by alternate movement, and by the oblique direction in which the power is exerted through the medium of the crank rod; 6th, the great pressure of steam required to work with any economy without a condenser; and 7th, the trouble of putting them in motion when they stop with the crank in a vertical direction, and the care required to prevent the fly wheel taking a reversed motion."

Before going into Mr. Masterman's remarks as to how far these faults are obviated, it may be worth while, in the first place, to see whether all of them exist. On this it may be said, that the first, second, third, and fourth, are evils which have justly occupied the consideration of nearly all mechanics since the general adoption of the steam engine, and are in reality evils of such a nature as to be evident to every one.

But in the fifth enumerated evil the author has fallen

into a very great though a very common error, in conceiving that power is lost by the oblique position in which the crank receives the force of the steam. We have had occasion more than once to lament that the erroneous idea ormed on this subject, has led many able mechanics into reat expense. Perhaps it is not incorrect to say, that ne half of the rotative engines which have been attempted, would never have been undertaken, had the different patentees been fully aware that no saving is effected by increasing the length of the lever upon which the steam exerts its force. These engines have generally been encumbered with an interior cylinder, or drum of such a diameter, as to cause a considerable friction, the purpose of such drum being to prevent the steam from acting near the centre of motion, where it was conceived it would be ineffective. Had this supposition been true, Mr. Masterman's engine would have had ten times the effect of any other: for the diameter of the experimental engine being 30 feet, the lever would be ten times more than the average length of a crank of a reciprocating engine of the same power.

The sixth disadvantage stated, as attendant on a reciprocating engine, is the great pressure of steam necessary to work it without a condenser. This is undoubtedly a difficulty which is of no small moment, and Mr. Masterman's engine (if it had succeeded in other respects,) would have bidden fair to have completely obviated it. The force of steam necessary to give motion to an annulus of a large diameter being as much less than that excited on a crank, as the length of the crank is less than the semi-diameter of the annulus. Hence a pressure of 7 or 8 pounds per square inch would have produced the same effect in this engine as 70 or 80 pounds per square inch would have produced, when exerted on a crank of 18 inches in length.

The seventh disadvantage stated—"is the trouble of putting a steam engine in motion, when it stops with the crank in a vertical position; and the care necessary to prevent the fly wheel taking a reversed motion." There is o doubt that it is a very great inconvenience, when the

engine stops with the crank in a vertical position, particularly in large engines; and we have frequently seen it necessary in such cases to call in the aid of several workmen, and lose a considerable portion of time before the engine could be put in motion, and that not unfrequently when considerable mischief has been occasioned by such a delay. But there are very few cases in which it is not expedient and absolutely necessary to have the power of reversing the motion of the engine. Mr. Masterman, therefore, assumes that to be an advantage which in reality is an insuperable objection to the general adoption of any machine not possessing the power of revolving either forwards or backwards. In steam boats particularly (where Mr. Masterman is sanguine enough to imagine his mercury engine could be applied with advantage) the capability of easily reversing the motion is a point of first consideration, and without such power, no one could guarantee their performing a voyage with safety.

Having shown that many of the objections here stated do not exist, we shall proceed to inquire, how far those which do, are obviated by this machine; and we shall first state that we have had frequent opportunities of inspecting the engine, which was erected by Mr. Masterman at Fawdon colliery, near Newcastle; the *troke* of which was 28 feet in diameter, and which *ought to have been*, according to his calculation, of 12 or 13 horses power. We are enabled therefore to speak from our own observation; in addition to which, we have been favoured with particular information on the subject, by the managing engineer of Fawdon colliery.

It appears that the "skill and nicety of workmanship" are by no means lessened in this machine, but on the contrary, the cost of it must greatly exceed that of the reciprocating engine. It is stated that "the *only* parts requiring any nicety are the valves, valve-seats, face, and masks, which must work steam-tight." Were these all, it will be readily conceived that the care required in fitting them up, must greatly exceed that of a reciprocating engine; there being no less than 28 surfaces of brass and

metal to be made perfectly smooth and steam-tight by the usual processes of filing, turning, and grinding; whereas in the common engine there are but two, requiring such nicety. It follows, therefore, that the cost as well as the skill required in the construction, must exceed that of the latter.

In remarking on the comparative friction of the two kinds of engines, it is observed, that "as the valves are regulated by the gravity of the weight, there is no friction in the pins." This is an error, since it is evident that these *weights*, by the falling of which the valves are worked, must be raised by the power of the machine, to the elevation from which they fall: as much force, therefore, must be exerted to elevate them, as would have been necessary to have moved the valves by the more direct action of the machine.

But these defects are of little importance, and scarcely deserve the notice we have given them. We shall now shew what appears to have been the cause of failure. This seems chiefly to have been the great condensation, arising from the exposure of the steam in the annulus. The steam occupying one half of the circle becomes dispersed, as it were, in a long bended pipe, which is subjected to the disadvantage of passing through the air, by which the condensation must be increased. Another cause of condensation is the difference in temperature between the depressed and the elevated surfaces of the water. The lower surface being continually in contact with the steam, is nearly of the same heat, whilst the upper surface is considerably colder. Now the different segments of the troke successively lose a portion of their caloric, as they *pass over* the cooler portion of the liquid; and in this cooled state become the recipients of the steam; and although there is a tendency in the machine to bring all parts of the water to an equal temperature, it was found preferable to prevent such a consequence, by a supply of cold water, as the elevated surface, when so heated, expanded into steam, and escaped through the discharging pipe.

Another and secondary cause of waste takes place, when

there is the least variation in the resistance of the load; when that is uniform, the steam exerts merely the force necessary to overcome it; but upon the resistance being increased, the steam then forcing upon the yielding surface of the water, without immediately producing the required speed, drives a considerable quantity of it over the upper part of the annulus, into the empty side of the wheel; and by occupying its place, rises by its inferior gravity upwards through the water, and escapes through the discharging pipe without producing any effect. When this takes place, it is some time before the water returns to its proper situation, or becomes a sufficiently steady abutment to produce the required powers.

The consequence of these defects was extremely apparent in the engine alluded to; the escape of caloric being such that few persons could endure the heat of the engine-house when the engine was working. The waste by condensation was so great, that it required a boiler of sufficient capacity to have worked a reciprocating engine of 36 horses power, merely to drive a small circular saw, which could have been easily driven by an engine of 2 or 3 horses power. The varied resistance produced by sawing wood, rendered the last-named defect very apparent; and, indeed, considering the degree in which its effect was weakened by the *irregularity* of its load, perhaps a saw was the most ill-judged application of its force.

We have been thus particular in our investigation of this ingenious machine, because several scientific friends were disappointed by its failure, and because both Partington and the author of Stuart's History have anticipated, that "if ever rotatory engines should be brought into successful competition with the common steam engine, it appeared probable that they might be constructed on this principle." We perfectly agree with the latter writer, however, in the opinion, that much credit is due to Mr. Masterman for his very clear and interesting account of his machine, and the candid appeal which he makes to experiment. We trust, in examining the pages of his little pamphlet, that we have been divested of every prejudice,

and that our apparently severe examination will be attributed to the proper motive. It is sincerely to be wished that more would follow his example, and fairly submit their inventions to the public, divested, like his, of all mystery and quackery; the advantages which would arise from this liberal proceeding would be incalculable.

It has been shown in an early part of this work, that a high-pressure engine consumes less fuel than a condensing engine of the same power, and that the force of the steam per square inch increases in a much greater ratio than the temperature communicated to the water. This fact fully establishes the superior economy of a high-pressure engine, and it also proves, that the more the pressure is increased, still less fuel *proportionably* will be required. Though this curious phenomenon is universally known, yet few attempts had been made in England to use steam of a pressure exceeding 50, or at most 100 pounds on the square inch, until the recent experiments of Mr. Perkins. This delay among our engineers to adopt what would seem to promise such great advantages, must be attributed to a caution which has been well grounded. The great danger of explosion must have been quite sufficient to have deterred them from the trial; and until that could be effectually guarded against, it would have been madness to increase the pressure of steam beyond its present limits. It is, indeed, no uncommon circumstance to find boilers in America loaded to double and sometimes treble the pressure of the greatest force we have now named; but still, with boilers of the usual construction, the danger must be very great, and the liability to accident such, as to more than counterbalance all the advantages that can be obtained.

Mr. Jacob Perkins, however, conceived that all this saving could be effected, and that danger could be removed, by reducing the size of the boiler. We shall give Mr. Perkins's own remarks on the subject:—

"It is a well-known fact that water does not boil under

atmospheric pressure until it has been heated to 212°, after which all the heat that can be applied cannot increase the temperature of the steam or water. Now, add an artificial atmosphere by loading the escape valve (the surface of which is equal to a square inch) with 14 lbs. and it will eceive 250° of heat, with a very little addition of fuel, and the pressure on the square inch will be doubled, or 28lbs.; the mechanical action will not be double, yet it will be increased much more than the consumption of fuel. Let the valve be loaded with two additional atmospheres, or 42 lbs., and the temperature will be raised to 280°, and will again produce double pressure, or 56 lbs. on the inch, and so on. If the generator be made strong enough, as I have no doubt it may be, to withstand 60,000 lbs. load on the escape valve, the water would not boil, although it would exert an expansive force equal to 56,000 lbs. on the inch, and be at about 1170° of heat, or cherry red. Water thus heated would, if it were allowed, expand itself into atmospheric steam, without receiving any additional heat from what surrounded it. It is not, however, necessary to heat the water to more than 500°, to have it flash into steam, if the generator be properly constructed."

a a is the generator, kept constantly filled with water up to the valve; *b b* is the furnace surrounding the generator, by which the water it contains is intensely heated, but is prevented from escaping, notwithstanding its great expansive force, by the enormous pressure upon the valve by the variable weight *d*; or until the pump *o* has forced a given quantity of water into the lower part of the generator, which raises the valve, and causes a like quantity of the heated water to escape into the pipe *c c*, where flashing instantaneously into steam, it rushes into the cylinder *g*, and drives the piston *f* to the farthest end of it; this action causes a communication to be opened into the pipe *k* into which the steam passes; the pipe *k k* passes through the condenser *l l*, delivering out its heat to the cold water contained therein; from thence, after descending, it takes an horizontal course, and enters the reservoir *m*, from whence it is re-pumped for use by the apparatus *o o*.

(*Jacob Perkins's Engine.* 1822.)

The arm *h* is attached at one end to the piston *f*, and is consequently moved by it in a horizontal line the length of the cylinder *g*, and the other end of the arm being connected with the fly wheel *i*, causes it to revolve; the fly thus put into action gives motion to the rotatory valve *e*,

which opens and shuts alternately a communication on both sides of the piston. An iron rod and chain *q* being fixed to the arm *h*, and at the other end to the loaded lever *p*, the pump *o*, is worked by the action of the arm, causing at every revolution of the fly a fresh quantity of water to be forced into the bottom of the generator, which again raises its loaded valve, and allows the escape of an equal quantity of water into the pipe *c c*, where flashing into steam, and rushing into the cylinder, it operates upon the piston again, and keeps up the alternating and rotatory motion of the several parts before mentioned.

The condenser *l l*, is a tube of copper about 4 inches in diameter, and 20 feet long, and is supplied constantly with cold water from the pump, through the pipe *n n*. This enters the condenser at the lower end, and is discharged at the upper end into the descending tube *r r*, which proceeding to the lower part of the apparatus, ascends in a spiral winding of many coils round the bottom of the furnace up to the valve *s*, loaded by a variable weight *u*, equal to 700 lbs. upon the square inch (or about 50 atmospheres); from the valve *s*, the tube descends as at *v v v*, and proceeds to nearly the bottom of the generator, as shown by the dotted lines. In order to ensure safety to the apparatus, a tube, *t t*, is fixed to the generator, and proceeds to the dial *r r*, showing the degree of pressure, or the number of atmospheres at which the machine works. Near to the middle of this tube is fixed a safety valve of copper, *x*, which is torn up when the pressure greatly exceeds the intended force. The atmospheric air contained in the spaces on each side of the piston escapes by tubes at *z z*, furnished with stop-cocks.*

This was one of Mr. Perkins's early modifications, and although there have been various alterations since, yet, as those have been nearly all in the engine, which of course has nothing to do with his principle, it is unnecessary to give them. The experiment, as far as it regards the generation of steam of this enormous pressure, has been quite

* Register of Arts and Sciences, vol. i. p. 369.

decisive; but the *economy* of engines on this principle has not been so fully established. It appears that Mr. Perkins's principal difficulty has been, not the generation of the steam, but its application to the machinery. This difficulty has been owing to the high temperature, which the cylinder and working parts acquire when in operation, which produces several inconveniences; the main one of which is, that it is absolutely impossible to lubricate the sides of the cylinder or valves with oil, tallow, or any such material, although it is well known, that metallic packing cannot be maintained, even in a condensing engine, tolerably steam-tight, without some such application; and if such a difficulty occur in a low-pressure engine, how much greater must that difficulty be in an engine, working at the great force of steam at which this is worked, especially when we consider the very subtile nature of such steam, and the much greater proportion that the openings, through which the escape is, bears to the surface of a piston on this principle, than similar openings in a metallic packing bear to the surface of a piston of a condensing engine. The reason why it is impracticable to apply oil, is, that the great temperature of the cylinder instantly carbonizes it, or causes it to pass off in vapour, and in that form to escape to the atmosphere. Another inconvenience is, that the materials of which the piston and valves are composed, become by wear and friction (both of which are increased by the cause just named) speedily destroyed.

In order to obviate some of these evils, Mr. Perkins has just taken out another patent, in which it is stated that he has discovered a method of forming a metallic piston, of a peculiar alloy, requiring neither oil, tallow, nor any lubricating material whatever, to reduce the friction; on the contrary, by the working of the engine, the rubbing surfaces of the piston and cylinder become so highly polished, as to reduce the friction considerably below that of the ordinary metallic packing when oiled.

There have been so many exaggerations and misrepresentations respecting this engine from first to last, that we cannot venture to give credence to any thing on the sub-

ject, without seeing this alleged improvement in actual practice, or attested by men of credit and respectability; certain it is, that Mr. Perkins's engine can never answer, without such an *alloy* as that alluded to; and it is equally certain, that if a material possessing these qualities has been discovered, its utility will not be limited to the steam engine alone, but will be equally applicable to machines of almost every modification.

Mr. Marc Izambard Brunel obtained a patent in 1823, for a very ingenious application of the steam engine, by which the connecting rods of two cylinders are made to give motion to the same crank: the following figure and description will enable our readers to understand it.*

Fig. 1. is a front elevation, and fig. 2. a plan or bird's-eye view of the engine, divested of the various gear and appendages employed in communicating its power, in order that it may be clearly and readily understood.

a a a is a strong triangular frame of cast iron, containing the two working cylinders, *b b*; these cylinders are inclined towards each other, so as to form an angle of 102°, that particular angle having been found by Mr. Brunel to be preferable to all others in effecting a rotatory motion to the crank, by the alternating action of the piston rods. *c c* are the piston rods; *d d* the connecting rods, attached to the revolving crank *e e*, which by its axis communicates motion to whatever machinery may be connected thereto; *f f* are metal rollers, running upon guide plates, to give support to the pistons, and thereby equalise their friction in the cylinders.

The steam is received from the boiler into the small cylinders *g g*, and, by the action of the pistons therein, the steam is alternately admitted into one of the ends of the working cylinders, *b b*, and a passage opened for its escape at the other. The action of the pistons in the small cylinders, *g g*, is effected by eccentrics, placed upon the axis of the main crank *e*, as may be seen at fig. 2; these eccentrics give motion to the rods *h h*, which, by the intermediate

* Register of Arts and Sciences, vol iv. p. 897.

FIG. 1.

(*Brunel's Engine.* 1823.)

levers shown, operate upon the pistons in the small cylinders.

A patent was obtained in 1824, by Mr. George Vaughan, of Sheffield, for a very curious application of the old open-topped or atmospheric steam engine, which we here give, not from any faith in the alleged advantages derivable from its use, but from the novelty of its appearance.

"Fig. 2. represents a section of the cylinder. *a a a a* is a cast-iron cylinder, open at both ends, and bored true; *b* a partition in the middle of the cylinder, *a*, which may be easily cast in, or bolted in afterwards; *c c c c* is a casing cast round the cylinder *a*, with a flange at the top and at the bottom, and another a little below the middle, to fix the cylinder in its place, which casing is for the purpose of

(*Vaughan's Engine.* 1824.)

heating the cylinder, and keeping it hot in the usual way: two side rods, *d d d d*, work through two copper or other metal pipes fixed between the casing and the cylinder, which pipes are rivetted to the top and bottom flange of the cylinder; *e e* are two cross bars connected to the side rod at both ends, and also to the top and bottom rods of the pistons. The upper piston is represented as nearly at the top of the cylinder. The piston rod is connected to the cross bar by a socket in such bar, which bar is suspended in the links of the parallel motion. *g g* are the two pistons and rods above alluded to, which, when connected with

the cross bars, *e e*, move together, producing what I call one stroke with two pistons. *h* is a cock and funnel for conveying grease through the casing and the cylinder to the bottom piston close to the partition *b*. *i* is a cock at the bottom of the casing, to let out in the usual manner the condensed steam from between the casing and cylinder. *k* is the cock and pipe to convey steam from the steam pipe into the casing of the cylinder; *l l* represent two passages which are cast in a branch proceeding from the cylinder and casing, the one passage communicating above the partition *b*, and the other below, to convey steam in and out from under the top and above the bottom piston. *m* is a passage to convey steam from under the slide valve into the condenser, which is cast in the same branch in the usual way. *n* is the slide valve inclosed in the steam box, having the steam pipe *o* connected with such box. The slide or other valve may be moved in any of the known methods employed for that purpose."

The steam being admitted, through the upper passage *l*, into the upper chamber of the cylinder, its piston is thereby thrown up, and the vacuum being immediately formed in the usual way, the pressure of the atmosphere of course operates instantly to thrust it down again, whilst at the same moment a corresponding effect is being produced upon the piston in the lower chamber, by the steam rushing into it through the lower passage *l*, thus co-operating with the atmospheric pressure from above, in producing what the patentee calls "one stroke with two pistons." A vacuum being next formed in the lower chamber, the atmospheric pressure acts upon the lower piston, while the steam, again admitted through the upper passage *l*, assists in like manner in throwing up both pistons as before, and thus by alternately allowing the steam to rush through the two passages *l l* into the upper and lower chambers, a constant uniform motion is produced and kept up.

The advantages stated to be derived from this engine are' that by the united application of the force of steam from the boiler on one piston, and the pressure of the atmosphere on another, a greater power is obtained, than

can be by the Bolton and Watt engine, where the air is excluded. The error of the patentee seems to have arisen from his not being conscious that steam acting in a boiler, at the pressure of 4lbs. on the inch, would, in a vacuum, exert a force equal to 4lbs. + the pressure of the atmosphere, or $4 + 14\frac{1}{4} = 18\frac{1}{4}$. When therefore we unite, as in the present instance, the pressure of the atmosphere to that of the steam, we obtain only $4 + 14\frac{1}{4} = 18\frac{1}{4}$, being the same result in both instances. This complicated machinery therefore answers no other end than that of increasing the friction, and adding to the expense.

Mr. J. C. C. Raddatz obtained a patent in 1825, for an invention of Dr. Ernst Alban, a physician of Rostock, in the grand duchy of Mecklenburgh. This latter gentleman came to England, for the purpose of introducing his invention, which consists, like Perkins's, of an attempt to reduce the consumption of fuel, by increasing the pressure of the steam; but Dr. Alban's apparatus is much more novel and ingenious.

The vessels wherein the steam is immediately generated, are of a very narrow compass, and made of tough metals, on which account they are very durable, although not constructed of any great thickness. They consist of tubes of small diameter, which are calculated to sustain a pressure of 4 to 6000lbs. to the square inch, thus removing all chance or possibility of their bursting; an event, which, even if it could happen, this construction would render perfectly harmless. These generating vessels have only about one foot of steam producing surface to the horse power, and in order that the generation of steam may be increased to such a degree that the intended effect can be produced, and in order at the same time to withdraw them from the destroying influence of the fire, they are placed within a medium, consisting of an easily fusibly metal, or metallic mixture, such as tin and lead, which is introduced into a tank or vessel of cast iron, and exposed therein to the action of the fire. In these latter, which Dr. Alban calls his metal vessels, he exposes a very extended surface to the action of the fire, without infringing on space, or

requiring any great quantity of the fusible metals or filling them, as may be easily seen by reference to the form of the metal vessel, fig. 2. By this means caloric is conducted in large portions to the medium, which being a good conductor of heat rapidly imbibes it, and forms, as it were, around the generator, a store of caloric, which it gives out so equably and rapidly, that the tubes, with but a small generating surface, collect and give out to the water which is to be converted into steam, as much caloric as if that surface had been ten times the size upon the ordinary construction. Both the metal vessels and the generator present an inconsiderable surface to the atmosphere, and in this manner the inventor has sought to prevent any condensation in the generator of the steam already generated, as well as to prevent, generally, any disadvantage resulting from the radiation of caloric.

The water is conveyed into Dr. Alban's generator, only in the quantity required to produce a given and continuing effect. For this purpose the forcing pump, by means of which the injections are supplied, is made to regulate itself in such a manner that it either moderates or entirely suspends the injection of water, according to the state of pressure in the generator. The steam generation is thus entirely independent of the management of the fire by the stoker, and is at all times subservient to the wants of the engine to which this apparatus may be applied. All possible danger would likewise be removed by this means, even in the absence of any safety valve. When it is required to stop the engine, it is only necessary to put the forcing pump out of action, and the generation of steam ceases of necessity.

In order to prevent the metallic fusion from being overheated, in cases where a smaller supply of steam is required, or where a suspension of steam generation takes place, by the stoppage of the engine, or otherwise, the inventor has arranged a heat regulator, which regulates the intensity of the fire. This apparatus indicates the degree of temperature of the fusion, upon which solely its action depends, and the generation of steam in the generator has

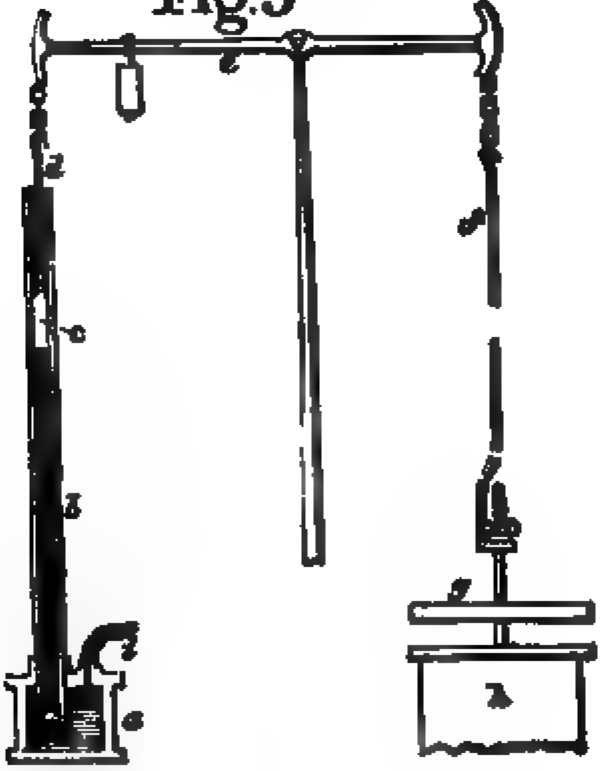
no influence whatever upon it; the regulator continuing to act when the generation of steam has ceased, on which account it is essentially different from any heat regulator hitherto used. Its application is indispensable to this apparatus in order to prevent so great a heating of the generating tubes as might occasion a decomposition of the water injected therein.

The very great saving of fuel anticipated from this invention is attempted to be accounted for, partly in consequence of the steam being produced at so very high a pressure, and partly by the circumstance, that the metallic medium, when in a state of fusion, is one of the best conductors of heat in nature, receiving and collecting the heat within itself very quickly, and without loss, and thereafter giving it out in a concentrated form to the generator. Owing to the constant motion kept up among the hotter and colder parts of the metallic fusion, as in the case of heated water, the more heated portion having a tendency to ascend, while the cooler part descends, the caloric is distributed very quickly and equably through the whole body. All congealment of the metallic medium is avoided, by using such an admixture of metals, as will fuse at a temperature lower than that which the steam receives within the generator. In ordinary boilers, the heat of the fire acts upon a bad conductor of heat, water, and upon a proportionable large body thereof; the parting with its heat cannot, therefore, be free or quick, and in order to produce any powerful effects, it is necessary to expose a very large surface of the boiler to the action of the fire.

For the reasons stated, it is, however, quite otherwise with this new apparatus for generating steam, and the surface exposed to the action of the fire is therefore considerably less, in proportion to the generation, than in ordinary boilers. The rapid generation of steam by this method, is likewise much favoured by the circumstance, that water is injected in small quantities only, and is distributed on all the sides of the generator.

Figures 1, 2, and 3, are representations of the generating apparatus, constructed in London, under the superinten-

Fig.3



(Dr. Alban's Steam Apparatus. 1825.)

dance of the inventor. It has a double metal vessel, and two generators; fig. 1, is a longitudinal section thereof; *a a a*, is the cast-iron metal vessel. *b b b*, the metallic mixture. Supported upon the lid or cover of the metal vessel, is the strong top of the generator *c c*, containing a cylindrical chamber of two inches diameter; *d d d d*, are the wrought-iron generating tubes, suspended in the metallic fusion; they are of 1⅛ inch bore, and are screwed into the top *c c*, so that they may be taken out whenever they require cleaning. *e*, is the injection pipe, made of copper, through which the water is conducted into the generating tubes, over each of which a small hole is perforated. *f*, is the steam pipe, connected with the engine and the safety valve.

Fig. 2. is a transverse section of the double metal vessel; it is freely suspended in the furnace, and exposed, on all its four sides and its ends, to the action of the fire, so that although it is but 4 feet long, 3¼ feet high, and, including the space between each vessel, takes up only 9 inches in width, it exposes to the fire a surface of sixty square feet. *a a*, is the double metal vessel; *b b*, the two generators; *c c*, the two injection tubes, which are joined together externally, and communicate in one pipe to the forcing pump. This pump is of the usual construction, furnished with a lever and weight, which are raised by the engine, through any of the known means. If the production of steam in the generator be too great for the wants of the engine, the pressure in the steam chamber will act against the injection, and the weight will be insufficient to force down the piston of the pump, which will thus remain inactive, until the pressure is diminished, by the ceasing of production, and the expenditure of the engine.

The heat regulator consists of two pipes filled with atmospheric air, one of each being inserted into each metal vessel, fig. 1. *g*, and surrounded by the metallic medium; to both pipes, very narrow tubes are fixed, fig. 1, *h*, and fig. 2, *i*, which are joined together externally into one tube, which opens inside the mercurial cistern, fig. 3, *a*; within the mercury therein contained, is immersed a vertical

tube *b*, with a float *c* swimming on the top of the mercury. This float is connected, by means of the rod *d*, with the lever *e*, and acts by the rod *f*, upon the damper *g*, which regulates the draught of the fire in the ash-hole. When the air in the pipes fig. 1, *g g*, becomes heated by the fusion, it expands progressively as this becomes hotter; presses on the mercury in *a*, fig. 3, and causes it to ascend in the tube *b*. By the rising of the mercury, the float *c* is made to ascend likewise, and acts by the rod *d* on the lever *e*, and thereby on the damper *g*, so that should the temperature of the fusion be greater than is required, it gradually closes the air hole *h*; the supply of air to the fire is thus prevented, and the heat is consequently diminished.

Of all the inventions which have lately excited the public attention, perhaps no one has been more the subject of discussion, than the apparatus patented in 1823, and again (for improvements) in 1825, by Mr. Samuel Brown, of London, and called a *gas vacuum engine*. This engine is intended as a substitute for the steam engine, and is actuated by the inflammation of hydrogen gas, in a vessel containing a portion of atmospheric air, sufficient for the combustion of the hydrogen. The oxygen of the air, then combining with the hydrogen, together form water, which of course occupying a less space than these in their original form, leave in the vessel a partial vacuum, the nitrogen of the air, and the impurities of that and the hydrogen gas only remaining. This vessel is made to communicate with the working cylinder, and the pressure of the atmosphere then acting on the piston, puts it in motion, which motion is continued until the equilibrium be restored, between the interior of the aforesaid vessel and the external atmosphere. But by using two of such vessels, and repeating the process of inflammation alternately on each, so that one of them may be giving motion to the piston, whilst the other is having its vacuum restored, the working part of the engine may be constantly kept up.

The principle of forming a vacuum by these means, has been long familiar to every one; the following simple experiment being one which, we doubt not, each of our readers

will remember to have heard of, when a child. Take a wine, or any other glass, small enough to be covered on the top by the palm of the hand, and having placed a small piece of lighted paper on the middle of the palm, (taking care to protect the hand from being burnt,) then covering the burning paper with the mouth of the glass, by pressing the latter against the hand, a partial vacuum is instantly formed, (by the combustion of the oxygen of the air in the glass,) sufficient not only to prevent the glass from falling, when the palm of the hand is turned downwards, but such as to require some little force to remove it from its hold. If this experiment be dexterously performed, it will perhaps give some pain to a delicate hand, from the great force with which the pressure of the atmosphere presses the flesh into the glass.

Mr. Brown's engine is a modification of this principle, and will, we doubt not, be fully understood by the following description :—

Inflammable gas is introduced along a pipe into an open cylinder or vessel, whilst a flame placed on the outside of, but near to, the cylinder, is constantly kept burning, and at times comes in contact with and ignites the gas therein; the cylinder is then closed air-tight, and the flame is prevented from communicating with the gas in the cylinder. The gas continues to flow into the cylinder for a short space of time, then it is stopped off; during that time, it acts *by its combustion* upon the air within the cylinder, and at the same time a part of the rarified air escapes through one or more valves,—and *thus a vacuum is effected*. The vessel, or cylinder, is kept cool by water. Several mechanical means may be contrived, to bring the above combination into use, in effecting the vacuum with inflammable gas, and on the same principle it may be done in one, two, or more cylinders or vessels. Having a vacuum effected by the above combination, and some mechanical contrivance, powers are produced by its application to machinery in several ways. First, water-wheels may be turned: secondly, water may be raised; and, thirdly, pistons may be worked.

The following is the description of an engine applied to

a water-wheel.—The two cylinders *c* and *d* are the vessels in which the vacuum is to be effected; from these descend the pipes *g i g* and *h j h* leading into the lower cylinders *x x*, from which the water rises along those pipes to fill the vacuum cylinders alternately. The water thus supplied, is discharged through the pipes B into the tank or trough *z*, whence it falls upon the overshot water-wheel, and by the rotatory motion thus produced, gives power to such machinery as may be connected to it. The water runs from the wheel, along a case surrounding the lower half, into a reservoir *v*, from which the lower cylinders *x x* are alternately supplied.

In order to produce the vacuum, the necessary quantity of gas is supplied to the cylinders by means of the pipe *k k k*, to be conveniently attached to a gasometer. The gas also passes along the small pipe *l l*, (communicating likewise with the gasometer,) and being lighted at both ends of that pipe, is constantly burning for the purpose of igniting the gas within the cylinders.

The water in the reservoir *v* passing down one of the pipes *w* into one of the lower cylinders *x*, causes the float *y* in that cylinder to rise, and pushing up the rod *o*, raises the end *b* of the beam, which of course draws up with it the cap *f*, and forces down the cap *e* of the other cylinder *c*.

The gas being admitted along the pipe *k*, the flame from the pipe *l* is now freely communicated to the gas in the cylinder through the orifice, by the opening of the sliding valve *s*, which is raised by the arm *r*, lifted by the rod *o*, by means of the beam.

To produce the intermitting action of each cylinder, some subordinate machinery is put in operation, by chains and rods attached to a glass or iron vessel *p*, partly filled with mercury, and, turning upon a pivot, each end receives its movements of elevation and depression, from the rise and fall of the projecting arms *q*, by the action of the beam above; the mercury being furnished for the purpose of regulating the supply of the gas into the cylinders, and the movement of the slide in the trough *v*. By the action thus communicated, the water from the reservoir flows

(*Brown's Gas Vacuum Engine.* 1823.)

down the pipe *w* into the vessel *x*, and produces the elevation of the float *y* and the rod *n*, and raises the cap *e* by the ascent of the beam at *a*.

The motion thus caused in this part of the machinery, operating upon its duplicate parts on the other side, of course produces by its action a corresponding movement; and the slider in the trough *v*, moved by the action of the mercurial tube *p*, being removed from its position, allows the water to fall into the other pipe *w*, and as it ascends, suffers the float *y* to descend, and rising into the main cylinder, thus lifts again the beam at *b*, and its connexions, and forces down the cap *e* on the top of the other cylinder.

After the vacuum is effected in the cylinders, the air must be admitted, to allow the water to be discharged and the caps to be raised: this is accomplished by means of a sliding valve in the air pipe *m m*, acted upon by chains *t t*, attached to the floats in the reservoir; and as motion is given to them, the valve is made to slide backwards and forwards, so as to allow of the free admission of atmospheric air.

Chains *u u*, with suspended weights, open the cocks in the pipe *k k*, and produce the alternate flow of the gas, and regulate and modify its supply.

In the pipes *g i g* and *h j h* are clacks to prevent the return of the water, when the air is admitted into the cylinders.*

When pistons are worked, the vacuum is effected (in the manner above described) under the piston, which is then pressed down by the weight of the atmosphere, and as an engine of that description is worked with two cylinders and pistons, the vacuum being produced in each cylinder, alternately, the fall of one piston raises the other, and, being alternately pressed down, the piston rods give motion to the crank and fly wheel. The air is admitted through large valves in the piston, and through orifices in the cylinders. An engine may be worked with one piston, the vacuum being produced in two cylinders (as in the water engine),

* Register of Arts and Sciences, vol. i. p. 397.

from which a pipe communicates with a third cylinder, in which the piston works, and into which the air is admitted alternately under and over the piston, while the vacuum extends to its opposite sides. By this contrivance a much greater rapidity of motion may be given to the piston, if required.

The ways being therefore explained, in which, by the pressure of the air, the vacuum produced (and continued) is applied to useful purposes, Mr. Brown claims to be the inventor of the combination above described for effecting a vacuum, *however much* it may be *varied* by the *mechanical means* with which it may be used, and also the inventor of applying a vacuum produced by the *combustion* of inflammable gas, to raising water, and to the production of motion in machinery by the pressure of the atmosphere.

The different scientific journals were much divided, as to the result of Mr. Brown's experiments: not that any one questioned the effective operation of an engine on this principle, such having been clearly established by actual construction, soon after the publication of the scheme; the question simply being, whether the apparatus could be purchased and maintained, at a less or at a greater cost, than the steam on the most approved construction. It would be needless to repeat the various inquiries on this subject, nearly all of them having been merely theoretical, and some of them written by persons unable to calculate from all the facts of the case. We have before us the report of a committee, appointed by the shareholders of a company called the "Canal Gas Engine Company," formed expressly for the purpose of trying on a large scale, and if practicable, of bringing into general use, Mr. Brown's engine. Mr. Routh, a director, stated, that "They had been appointed to ascertain the practicability of Mr. Brown's engine, for the application of gas instead of steam, to the propulsion of vessels either on canals or navigable rivers. Two experiments had been made; the one on the 1st of January, and the other on the previous day, under the inspection of the committee. The gentlemen who were entrusted to examine and report to the shareholders, dif-

fered greatly in their opinions derived from those experiments; but they were now ready to state their individual opinions on the subject, which was certainly one of great national importance. The day on which the first experiment was made, being extremely boisterous, was particularly unfavourable to the performance of the experiment, inasmuch as the boat itself was leaky, and the machinery defective. The boat then made way, but not in such a manner, as to give a highly advantageous opinion of the powers of the engine. In the second experiment, however, it was in a more perfect state. The boat, which was started from Blackfriars Bridge, went at the rate of from seven to eight miles per hour, with all the regularity of steam boats; the paddles moved as regularly; and it appeared the power of the engine might be sustained for any length of time by gas, as well as by steam. It was the opinion of most persons present, that the engine answered every purpose expected of it; and he owned that, as far as power went, it was his own opinion; but he considered that the expense of procuring gas would entirely prevent its application as a prime mover, instead of steam.—It was said that gas could be readily and cheaply procured by the decomposition of water. We understood the chairman to express himself of opinion, that this proposition had not been yet made out. He was decidedly of opinion that the company ought to be dissolved. In fact, it was impossible that it could go on. The sum of rather more than £5000 had been subscribed. £1000 had been given to Mr. Brown, for the share of his patent right in the invention; £1000 more had been paid for constructing an engine, under his superintendance, for the application of his principle, which had failed. £1700 was locked up in the hands of their bankers, Sir John Perring and Co.; then £300 was paid for a boat, and the remaining available funds were otherwise absorbed. The company could not, therefore, proceed without another call, which could not of course be made, or, if made, attended to."

On the other hand, it was stated by Mr. Brown, "that the experiment had succeeded to the full extent contem-

plated by himself and friends. On the first time of the experiment, the engine itself was not got into any state of completeness, until the midnight preceding the morning of trial, and the boat was accidentally run on shore, and stove in her side. They had to make the experiment on a boisterous day, and before this accident was repaired, the paddle-wheel was found to be too small, and deficient in power. A second experiment was made on the river, before the Lords of the Admiralty and a number of scientific men, and the result was such as to confirm their minds in favour of its eligibility. He would state further, that it would, without doubt, be adopted."* He did not, however, shew by figures, or any other calculation, that gas could be obtained at such a cost, as to allow a fair competition with the steam engine; and we are therefore inclined to give full credit to the statements of the chairman and directors, namely, "*that the expense of procuring gas would entirely supersede its application as a prime mover, instead of steam.*"

Previously to the year 1823, carbonic acid had never been exhibited but in the gaseous or aeriform state, and it was a commonly received opinion, that no degree of pressure nor of cold would cause it to assume a more concentrated form; in the early part of that year, however, Mr. Faraday of the Royal Society, under the direction of its then illustrious president, Sir H. Davy, succeeded in reducing it (as well as several other gases) into a liquid state, by the mechanical pressure of a condensing pump.

This liquid, at the temperature of freezing water, in its endeavour to assume the aeriform state, exerts an expansive force equal to 30 atmospheres; at ordinary temperatures, a force of from 40 to 50 atmospheres; and on a heat of only 120° Fah. being applied, the force is increased to 90 atmospheres; the pressure increasing in a similar ratio for higher degrees of heat; in other words, at the rate of about 11 or 12 pounds increased pressure upon the inch, for every single additional degree of heat.

* Public Ledger.

We may easily conceive that to construct an apparatus by which a power so immense, and apparently so economical, might be rendered available, like the steam engine, as a first mover to all kinds of machinery, has occupied the attention and study of many of the most scientific and clever men, not only of this, but of every country in the civilised world; since it cannot be doubted that the paper of Sir H. Davy, "*on the application of liquids formed by the condensation of gases as mechanical agents*," has been published every where, and translated into the language of every country where mechanics are studied as a science. Nearly four years have intervened since the publication of the important facts detailed in the paper alluded to, during which period, not only individual talent, but the abilities of one of our first chemists have been united with those of one of our most eminent engineers, for the accomplishment of this great desideratum. In this honourable spirit of rivalry, the talents of Mr. M. I. Brunel have been employed, and he has so far satisfied himself of the advantages arising from such an apparatus, as to have procured a patent for an engine on this principle.

It is proper that we should here remark, that the patent right for Mr. Brunel's apparatus is not limited to the employment of carbonic acid, but that it extends to all liquids which are the result of the condensation of the gases. The preference being however given to the former, we may perhaps infer that the engine we have to describe, is better adapted to the peculiar properties of carbonic acid gas, than to those of the others. Carbonic acid gas may be obtained by decomposing any of the carbonates by the action of the common acids. The mode of obtaining the liquid from the gas, is by forming the gas under a gasometer, and condensing it afterwards in another vessel, by means of a condensing pump, and continuing the operation until it passes to the liquid state.

The apparatus, as shewn at fig. 2, consists of five distinct cylindrical vessels; the two exterior vessels *a* and *b* contain the carbonic acid reduced to the liquid form, and are called the *receivers;* from these it passes into the two

adjoining vessels *c* and *d*, termed *expansion vessels;* these last, having tubes of communication with the working cylinder *e*, the piston therein (shewn by dots) is operated upon by the alternate expansion and condensation of the gas, giving motion to the rod *f*, and consequently to whatever machinery may be attached thereto.

As the working cylinder *e* is of the usual construction, no further description of that part of the apparatus is necessary; and as the two vessels on one side of the cylinder are precisely similar to those on the other, a description of the receiver *a*, and the expansion vessel *c*, will apply to their counterparts *b* and *d;* the two former, (*a* and *c*) are therefore given in a separate figure, (1) on a larger scale, in section, that their construction may be seen, and their operation better understood. The same letters of reference designate the like parts in both figures.

The communication of the condensing pump (before mentioned) with the receiver *a*, is through the orifice *g*, which can be stopped at pleasure by the plug or stop-cock *h*. When the receiver has been charged with the liquid and closed, a pipe *i* is applied, and connected to the expansion vessel *c*, at *k*. *l l* is a lining of wood (mahogany) or other non-conductor of heat, to prevent the absorption which would otherwise be occasioned, by the thick substance of the metal. The expansion vessel is connected, through a pipe *m*, to the working cylinder *e;* these vessels contain oil, or any other suitable fluid, shewn at *n*, as a medium between the gas and the piston.

The receiver is a strong gun-metal vessel, of considerable thickness, in the interior of which are placed several thin copper tubes, as represented at *o o o*; the joints of these tubes, through the top and bottom of the receiver, are made perfectly tight by packing. The use of these tubes is to apply, alternately, heat and cold to the liquid contained in the receiver, without altering very sensibly the temperature of the cylinder. The operation of heating and cooling through the thin tubes *o o o*, may be effected with warm water, steam, or any other heating medium; and cold water, or any other cooling medium. For this

purpose, the tubes *o o o* are united by a chamber and cock *p p*, by the opening of which, with the pipes *o o*, hot and cold water may alternately be let in and forced through, by means of pumps, the cocks being worked in a similar manner to those in steam engines.

Now, if hot water, say at 120°, be let in through the tubes of the receiver *a*, and cold water at the same time through the receiver *b*, the liquid in the first receiver will operate with a force of about 90 atmospheres, while the liquid in the receiver *b* will only exert a force of 40 or 50 atmospheres. The difference between these two pressures will therefore be the acting power, which through the medium of the oil, will operate upon the piston in the working cylinder. It is easy to comprehend that, by letting hot water through the receiver *b*, and cold water through the opposite one *a*, a re-action will take place, which will produce in the working cylinder *e*, an alternate movement of the piston, applicable, by the rod *f*, to various mechanical purposes, as may be required.

Mr. Brunel has not yet constructed an engine on this principle, so that its utility has never been put to the test of experiment. The dreadfully fatal effects which have been produced by inhaling carbonic acid gas, are too well known; and it is to be feared that no working machine could be constructed, but what, with such an internal pressure, must be subject to considerable leakage, and consequently every such engine must endanger every person who approaches it; for such are the instantaneous effects produced by this gas, that instances have been known where it has proved fatal three seconds after inhalation.

We have mentioned, more than once in the course of this work, that metallic pistons have been considered as a very useful substitute for those which are packed with hemp or cotton. We have already given, at page 76, a description of one invented by Mr. Cartwright, which, as we observed, is continued to be used to this day. We are now about to describe that of Mr. Barton, patented in 1818, and explained as follows.

The annexed figure gives a horizontal section of Mr.

Barton's piston. It is composed of three segments *a a a*, forming together a circle; they are made either of brass, or cast steel, hardened and tempered. These segments are preserved in their places by three triangular metal wedges *b b b*, which act equally upon them by the pressure of the three strong helical springs *c c c* working over three steel pins (not shewn). When the segments become worn, the wedges are protruded forward by the force of the springs, and fill up the space they would otherwise leave unoccupied; by which a perfectly close contact is uniformly preserved for a very considerable period of time.

On the exterior or periphery of the circle formed by the segments and wedges, three grooves are made all round; the upper and lower are to contain two metal rings with a cleft across each, which just fit flush into them; these serve to keep the several parts together, so as to prevent any displacement in putting in or taking out the piston from the cylinder. The middle groove is for the purpose of holding grease or oil, to lubricate the piston and cylinder.

Mr. Barton has succeeded in bringing this kind of piston into use somewhat extensively, and has obtained the certificates of several respectable persons, as to its effectiveness and utility: from among these, we quote the authority of Messrs. Thornbill and Morley, of New Bond Street, who state, that previously to the adoption of Mr. Barton's piston, they required the steam to be raised in the boiler, to the pressure of 73 lbs. on the inch; but that since that time, their engine can do more work with the steam at 43 lbs. only; and that during three years they had not a single stoppage, as it continued perfectly tight.

The objection which is urged against this piston is, that the wedges *b b b*, advancing forward as they become worn, quicker than the segments *a a a*, there will be a tendency in them to cut grooves in the cylinder, by their points constantly working up and down, or that if they should not produce this effect, then they will be prevented (by the resistance of the cylinder) from forcing out the seg-

ments so as to keep them tight against the sides, and thereby prevent the steam from escaping past them. It is also contended, that as the segments are worn away, they will not fit closely to the circle of the cylinder, because the curvature of a small circle never can be in contact with that of a larger, excepting in one point. In reply to these objections the inventor appeals to the actual experiment, and certainly it appears that practice has not warranted these conclusions; it being found, that those points which are most forcibly pressed against the cylinder, are the soonest worn away, and therefore that the points of the wedges, and those parts of the segments, which are most forcibly pressed against the cylinder, are sooner removed by this self-correcting process; so that the whole is kept perfectly circular, and in close contact with the cylinder.

A patent was also obtained by Mr. William Jessop, of Butterley, Derbyshire, for a metallic piston, which is formed only of one piece, of a spiral figure, as below.

The piston is first to be bound round with hempen packing, as a bed for the metallic portion, and to prevent the escape of the steam. The spiral spring is placed between the upper and lower plates of the piston, through which screw bolts are passed, and by turning the nuts, the plates are brought nearer to one another, and the metallic coils are thereby pressed closely together. Thus restrained above and below, the metallic coil is to expand and contract laterally against the sides of the cylinder, and while it shall effectually prevent the escape of the steam, to press with the requisite force, uniformly, so as to produce very little friction.

On this plan it may be said, that though the method of tightening the packing as it wears, is simple and easy, yet

it does not obviate one of the objections against hempen packing, namely, the danger that a careless, or even an experienced workman, may screw it down so tight, as that nearly all the power of the engine will be absorbed by giving motion to the piston. Though perhaps this will appear a matter of trifling importance, as it will be answered, that such a fault can be easily corrected, yet it is found, that many engine-men are extremely careless on these matters, so that it is desirable, if possible, to have the piston of such a construction, as to be entirely out of their power. However, in the hands of an ingenious and attentive engine-man, these pistons are found to be very useful and economical.

A great variety of forms have been given to the metallic piston: generally, however, they partake, in some degree, of the principles of those described.

A patent was obtained, in 1823, for a Rotative Engine, by Messrs. Beningfield and Beale, of London, which resembled in principle those of Messrs. Cartwright, Malam, Routledge, and Chapman. It differs, however, from most of these in some points, namely, that its external cylinder revolves, whilst the interior one is stationary, and the motion is communicated to the machinery by a spur wheel on the cylinder working into another spur wheel on the shaft. The internal arrangements of the engine approach the nearest to Chapman's, of any of the above engines, the difference being that the leaves or valves are fixed to the exterior cylinder, and the piston or steam stop to the interior cylinder. There are many ingenious contrivances for the simple working of the different parts, and for keeping the whole apparatus steam-tight without much friction; and judging from the small engine which we have frequently seen in operation, and which has been working for nearly three years at the manufactory of Beningfield and Co. we are inclined to judge more favourably of this rotative engine than any we have yet noticed. On a small scale, there is no doubt of its utility, and we can see no reason why a large engine should not be found effective.

Captain Walter Foreman, of Bath, obtained a patent, in 1824, for a rotative engine, which is thus described.

Fig. 1. is a side view of the steam-wheel, with the casing removed, to show the situation and construction of the valves, and their mode of action in the steam-way. *a a* is the steam-wheel, revolving upon its axis *b*. *c d e f g h* are six flap valves, having steam-tight joints, and fixed to six blocks on the periphery of the steam wheel; three of the valves are shown open, and three closed. *i* is a fixed stop for arresting the course of the steam; it is composed of an upper and lower piece, accurately fitting the sides of the chamber, and connected together by means of screw bolts, so contrived as to admit of an easy adjustment when the lower curved surface may become worn, by the friction of the periphery of the steam-wheel in its revolution. *o* is the anti-friction roller, fixed to a springing curved arm, and screwed to the stop *i*.

Fig. 2. is a vertical section of fig. 1., through the axis; *a a* the steam wheel, *b* the axis, *g h* two valves, by which are seen their tapering figure, and the conical form of the casing which encloses them; the lower valve is shown as closing the steam-way, and the upper one as leaving it open. It will now be perceived that the valves from this peculiar shape do not, when moving backwards or forwards, even touch the sides of the casing; consequently, all friction in those parts is obviated; the dotted lines in the upper valve are intended to illustrate this observation,

(Captain Foreman's Rotary Engine. 1824.)

as they describe the course of the extreme edge of the valve, when in the act of opening or shutting the steam-way.

The mode of operation with this engine is as follows:— Steam is admitted by the tube *j*, which immediately fills up the space between the stop *i* and the valve *c*, and the latter yielding to the expansive force of the vapour, gives motion to the wheel *a a*; when, in the revolution, the valve *h* takes the place of *c*, the flap of *h* (swinging upon its joints) falls by its gravity into the same position; the steam then acts against it in like manner as *c*, and successively the valves *g f e d* in rotation, as fast as the wheel revolves, the steam finally escaping at the pipe *k*; the friction-roller *o* pressing down each flap, as they pass under its operation, against the periphery of the steam-wheel.

The only novelty in this engine is the form of the valves, which are not rectangular, like those of other rotative engines on a similar principle, but taper outwards. The reason of their being of this form is, that there may be no friction from their sides rubbing against the lids of the cylinder, except when they are opened out, as at *c d e*: and further, that as they become worn it is calculated they will still continue tight, because all the three bearing sides will, by being a little further opened, press upon the several surfaces over which they pass, and so continue to be steam-tight. Though, perhaps, a valve of this form, acting in a circular channel of the shape here given, may continue steam-tight for a great length of time, yet it unfortunately happens that a leakage is produced in another way by the wearing of these valves, as great, if not greater, than could have been by the wearing of rectangular valves.

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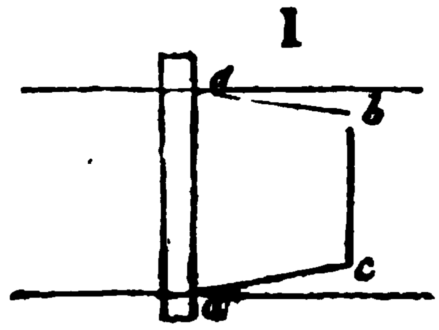

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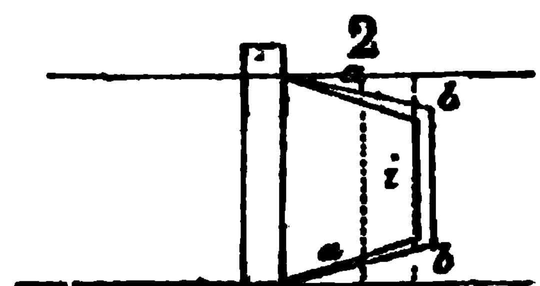


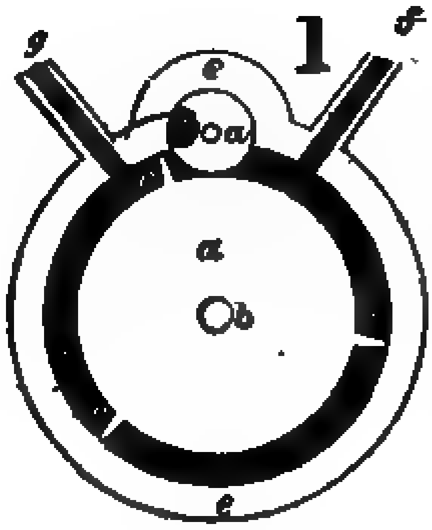
These valves must, in order to pass under the steam-stop, fall into recesses in the interior cylinder, of the form of fig. 1, and if very accurately fitted to the sides of the recess (a very difficult operation) may at first be tolerably steam-tight; but by the continued wearing of the three working sides of the valve, *a b*, *b c*, and *d e*, against the cylinder and lids, the valve then will become too small for the recess, and appear when shut as in fig. 2. Now, supposing the stop, *i*, to be represented by the dotted lines, it will be evident that whilst the stop and valve are as there shown, the steam can freely enter the opening between the valve and the sides of the recess, and escape through that opening (say from *a* to *b*). Therefore, as there is at all times one or other of these valves under the steam-stop, the leakage of course will be constant, and in a short time so great as to render the engine quite ineffective and useless. Of the great friction we say nothing, having already treated of it, when speaking of the engines which nearly resemble this in all the points except the variation here described.

A patent was obtained in 1825, by Mr. Joseph Eve, (late of the United States, but now of Liverpool,) for a Rotatory Engine, the following description of which we extract from his specification.

Fig. 1. presents an end section; fig. 2. a longitudinal section of the said engine, on the simplest manner of construction. The same letters refer to similar parts in all the figures.

"*a a*, are the cylinder and cone, revolving in contact in opposite directions, the cone having one groove, and being one third of the diameter of the cylinder, which latter has three wings or pistons *c c c*, the ends of which, as they revolve, touch the outer case *e*, and do not admit any steam to pass. The steam is admitted through the pipe *f*, and acting on the wing *c*, causes the cylinder to revolve until the said wing passes the pipe *g*, when the volume of steam lodged between each two wings, is allowed to escape. The wing, which has thus passed, falls into the groove *d* of the cone, the bottom of which groove it touches in

1



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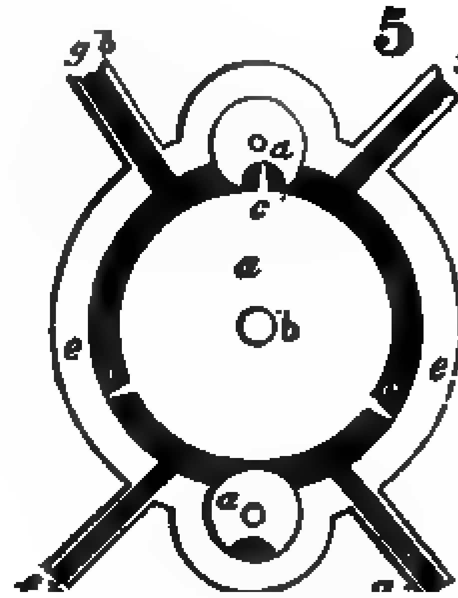

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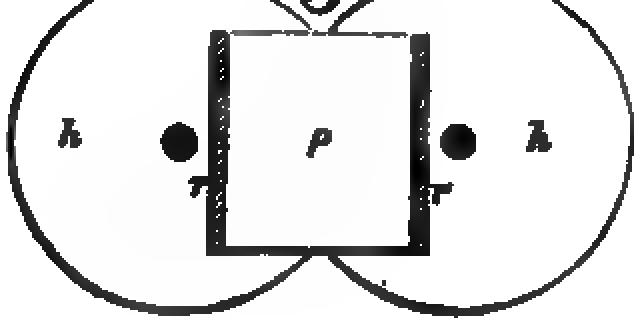
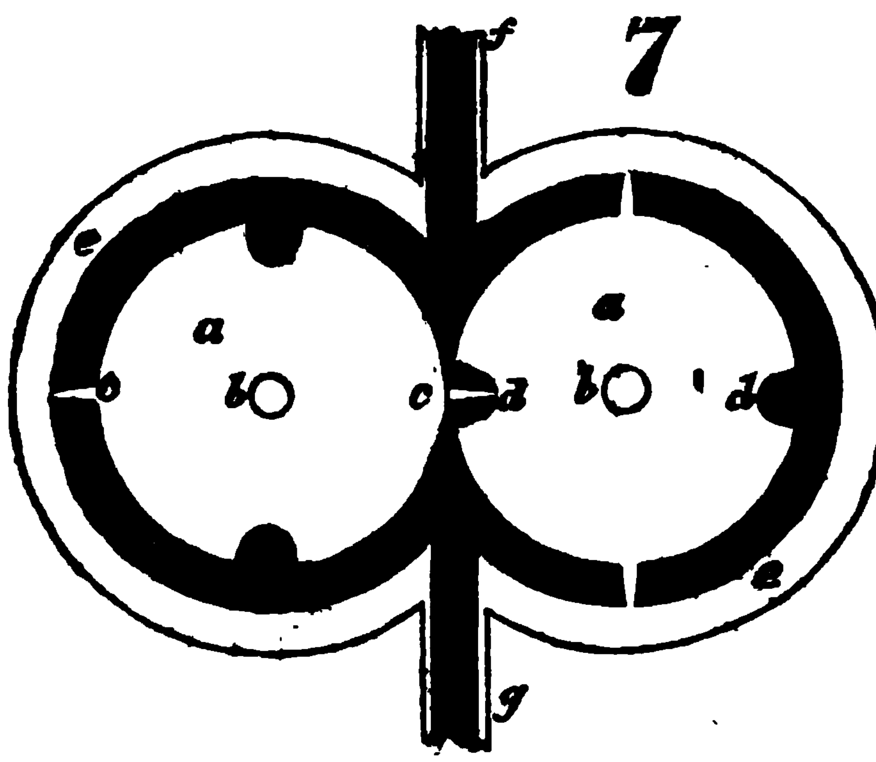


(*Eve's Rotary Engines.* 1825.)



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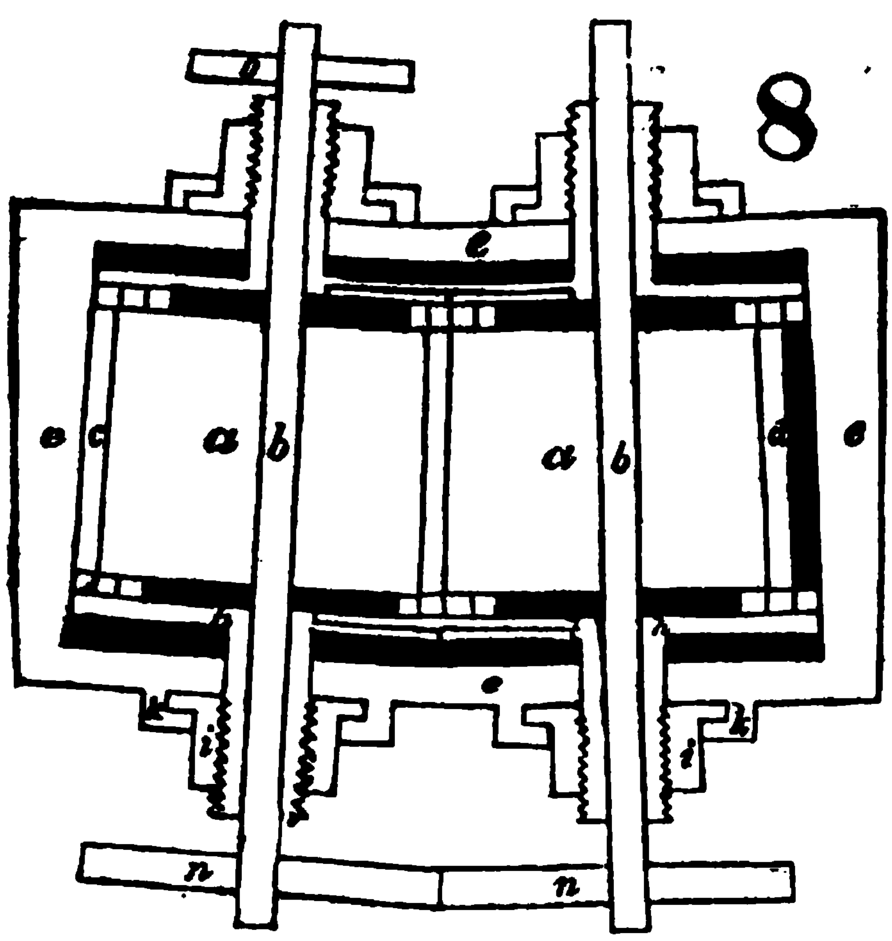

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(*Eve's Rotary Engines.* 1825.)

passing, thus allowing no steam to escape between. The said wing *c* then passes again by the steam pipe *f*, and is acted upon as before described, and so on in rotation. The cylinder *a*, which is firmly fixed to its axis *b*, rests on one side on the outer case *e*, through which the axis projects; but as there is some friction produced by the revolution of the said cylinder at its two ends touching the outer case, I have placed a false end *h h*, under the opposite end of the cylinder, which false end slides on the axis *b* freely, and has a thread cut at the end, by means of which, and the adjusting nut *i*, the cylinder, if worn at the two

ends, can be easily tightened and adjusted. The adjusting nut is confined by the collar *k*, which collar is screwed to the outer case. The conical shape of the small runner, which can likewise be moved upwards or downwards in the outer case, serves to keep the two convex surfaces of the cylinder and cone in contact.

"The groove *d*, in the conical runner, is cut into a separate piece of metal, which slides by an adjusting screw *o* up and down; so that when the engine is adjusted, the groove *d*, on the piece of metal, into which the said groove is cut, can be moved up and down, so as to fit the wings of the cylinder.

"Letters *n n*, in fig. 2, represent two cog-wheels running into each other, attached on the outside of the engine to the axis of the cylinder and cone, placed there for the purpose of producing a corresponding revolution of the said cylinder and cone, thus causing the groove of the cone to present itself regularly to the wings of the cylinder; *o* is a pinion fixed to the other end of the axis, by means of which any machinery can be put into motion.

"Another variety of constituting a steam engine on this principle is shown by an end section view in fig. 5, and an external view in fig. 6. This engine has a cylinder with two small conical runners on each side, the said conical runners being of the same construction as before described, with one groove cut into each, and being one third of the diameter of the cylinder. There are two induction and two eduction steam pipes, and, although the engine may be, with the exception of the addition of one of the conical runners, exactly of the same size as the one first described, a double quantity of steam is requisite, and twice the power of the former engine is gained: the steam enters through the pipe *f a*, and acts on the wing *c*, which after having passed pipe *g o*, where the steam escapes, falls into the groove *d* of the lower cone, and appearing at the induction steam pipe *f b*, is loaded again with steam pressure, which it discharges at the second eduction pipe *g o*, and then enters the groove of the upper cone, which having passed, it is loaded again at the first-mentioned induction pipe.

"Letters *m m* are bridges, by which the spindles on axis *b b b* are supported. This engine has three cog-wheels *n n n* attached to the three spindles, so as to cause the cylinder and cones to revolve in unison, and, like the first described engine, a pinion *o* on the opposite end of the axis of the cylinder. Fig. 7, shows an end section; fig. 8, a longitudinal section; and fig. 9, the exterior.

"The two conical runners in this engine are of an equal length and diameter, each has two wings or pistons attached, and two grooves cut into it, and in revolving in opposite directions, the wing of one runner falls alternately into the groove of the other. The steam enters by pipe *f*, and as the cylinders are running in contact, it cannot escape between them, but acts upon the two wings in opposite directions, and escapes at the eduction pipe *g*, after the said wings have passed the same. By reference to fig. 8, which represents a longitudinal section, it will be seen that the two cones have each two false ends *p p*, sliding freely on their spindles; the two outer cases *e e* fit over the runners and their wings exactly, each of the four false ends has an adjusting nut, by which the engine is tightened, if steam should escape, or slackened, if it should run too tight. Each pair of the false ends, where they join, have a plate that connects them and breaks their joints, so as to prevent an escape of steam; this plate *p* slides into the groove *r*, cut out of the false ends, as exhibited by fig. 3, and fig. 4, the former shewing an end view of the false ends with the connecting plate in the middle. On these false ends packing rings, *g g g*, which are confined to the sliding plate as exhibited in the latter figure, are placed. These rings press against the hollow outer cases, and prevent any steam escaping by them. These packing rings are shown in section, in fig 8. It will be evident that the false ends need not be made true, if the connecting plates and packing rings, as above described, be adopted, and that the engine, if provided with moveable false ends, conical runners, and the afore-described connecting plates, and packing rings attached, as shown in fig 8, can always be kept steam-tight, and by use the various parts, on which there is any friction, will fit better.

This engine approaches nearest to Mr. Flint's, described at page 183, and is of course liable to the same objections.

A patent was obtained in 1826, by Louis Joseph Marie, Marquis de Combis, for an improved Rotary Engine, the principle of which is as follows:—

"A piston is made to circulate within a vertical hollow ring, by steam admitted alternately at two opposite points of the diameter of the latter, and discharged through perforations in the central boss of the piston, and in its tubular axis; which hollow ring is separated into two equal portions, by sliding valves, that pass across its cavity on to the axle, at its different sides, and which are withdrawn successively as the piston approaches to them, and are instantly replaced as soon as it has passed.

"The form of the case that contains the hollow ring may be conceived by supposing a flat cylinder with its angles rounded off, from which, rectangular pieces project at opposite sides of its diameter, to contain the sliding valves. This case is divided into two equal portions, by a section through the middle of the axis of its cylinder, and at right angles to it, each of which portions is again divided into two equal parts by another section, that passes in the plane of the axis, and through the midst of the valve receptacles; the four pieces, thus formed by the two sections, are united by screw bolts and nuts, passed through flanches cast on them for their reception. A perforation is made through the middle of the cylinder, in the line of its axis, whose diameter is between three and four times greater than that of the revolving axle of the engine that passes through its centre; and at equal distances from it, all round close to the sides of the cylinder, is formed the annular cavity, or hollow ring, in which the piston moves.

"The axle of the engine projects a considerable distance beyond the cylinder at each side, to allow space on it sufficient for the reception of the main wheel (by which it gives motion to the machines with which it is connected,) for the fly-wheel, and for the parts that impel the apparatus, which works the sliding valves of the hollow ring, and

those of the steam box which communicates with the opposite sides of its diameter. In the middle of this axle is a boss, or enlarged part, of the full diameter of the perforation of the cylinder, but only of the thickness which is found necessary for an arm, that passes from it to the piston at right angles to the axle, whose breadth regulates its size: and for the revolution of which, along with the piston, a circular cavity is left between the two lateral divisions of the cylinder.

"To make the cavities steam-tight at each side of the boss round the axle, there is first a layer of hemp packing put in close to it at each side; secondly, a cylindrical piece is placed over that, round the axle, which closely fills up the whole central perforation through the cylindrical part of the case, in the external portion of which piece a hollow cone is formed, with its apex next the boss, from the top of which, ears project at each side, through which screws pass that draw it towards the case, and thereby compress the packing between it and the boss; and, thirdly, a conical piece, perforated to receive the axle in its centre, and ground so as to fit the conical cavity truly, is placed over the hole, and connected by sliding side-pieces to the axle so as to turn along with it; while from other pieces, also attached to the axle, screws parallel to it project so as to press it towards the centre.

"The piston (which is called a sole, by the patentee) is made steam-tight by two layers of metallic packing, (each formed of three segments of a circle equal to it, having three triangular pieces pressed into the angular cavities, formed at their points of junction by helical springs that proceed from the centre,) whose principal pieces are so arranged, that the joinings in one layer are covered by the middle parts of those in the other layer; and the sliding valves that pass across the case horizontally through the hollow ring to the axle are made steam-tight at the sides, by fitting closely to the parts of the case through which they pass, and next the axle by a metallic packing pressed towards the latter by springs; and as it is expedient that these valves should be thin, that the piston may pass the

cavities through which they slide, with more facility, to give them at the same time sufficient strength, ribs are fixed to their faces in the direction of their motion, for which there are corresponding grooves formed in the projections of the case, into which they are received; which projections extend sufficiently to enclose them at every side, only being perforated opposite the middle line of the slides, to allow of the passage of rods, that proceed from them through stuffing boxes, similar to piston rods, by which rods they receive their motion.

"To connect the main wheel with the axle, two circular discs are fixed to the latter, so that one of them may be pressed toward the other, by screws from other parts proceeding from the axle; and the main wheel being placed between these discs, with its centre on the axle, is so compressed between them, that it revolves with them, so long as the resistance of the work to which it is applied is less than that caused by the pressure or friction of the discs; but should the former become the greatest, from any accidental obstruction, the discs will pass round without moving the main wheel; by which means the destruction of material parts of machinery will be prevented, which might otherwise be liable to occur.

"To one of these discs just mentioned, a flat-toothed plate is attached, whose shape and teeth correspond with those of two eccentric spiral-toothed cams, one of which is placed at each side of it, and from which connecting bars proceed two crank pieces, which by these cams move forward and retract the sliding valves of the hollow ring, at the proper periods; at the parts of these cams that are farthest from their centres, the teeth are serrated, but at those which are more centrical, and where they approximate to the form of circles, the teeth are similar to those in common use.

"The steam passes from the boiler, that is not described, by a tube furnished with a cock, (by which the passage can be diminished as desired,) to a steam receptacle of a semi-annular form, and of about the same size as the hollow ring, which is placed parallel to this latter. From

the opposite ends of this receptacle, tubes pass to the hollow ring close to the sliding valves; in which tubes, where they proceed from the receptacle, are fixed other sliding valves, called cocks, by the patentee, which are moved by a system of crank levers and connecting bars, something similar to that used for the valves of common steam engines, which receive their primary impulses from arms attached to the axle of the steam engine in such a manner, that the times and degree of their impulses may be varied so as to diminish or increase the quantity of the steam admitted to the engine, by a little apparatus fixed to the axle, which could not be well explained without a drawing.

"These valves of the steam tubes, and the larger slides of the hollow ring, are moved so, by the means described, that as soon as the piston passes one of the latter and it becomes closed, the steam tube, that enters the hollow ring close to this slider and between it and the piston, is opened, and the tube at the opposite side becomes closed, which latter, in its turn, becomes opened, as soon as the piston has passed it and the slide at the side close adjoining.

"The steam, after passing out from the hollow ring through the perforation in the boss and the tubular passage in the axle before-mentioned, enters a condensing vessel, where the greatest part of it is condensed into water, and through a spiral tube or worm in the vessel, runs from thence by a pipe into a closed reservoir, which communicates with the bottom of the pump that supplies the boiler; to which pump also another pipe rises from the cold water well, which being below the level of the reservoir, the water only ascends from it, when the latter is empty; and when the boiler is sufficiently full, the pipe of supply is closed by the rising of a balanced floating weight. This pump is worked by a revolving crank, that communicates with the main axle, and which turns in a horizontal slot, in a piece attached to the top of its piston rod.

"An open oil vessel is placed at the top of the hollow ring, from which a pipe passes into it, that is closed by a cock made to turn round very slowly by a pinion attached to it, in which another pinion works, whose axis extends to one of the discs on the main axle, where a wheel is fastened to it, into which a pin projecting from the disc strikes, once in each revolution of the latter, and moves it forwards the extent of a single tooth."*

This engine comes nearest, in its principle, to that patented by Mr. Joseph Turner, in 1816, the form of the sliders and piston, together with some of the interior arrangements, being nearly similar. Some of the improvements are very ingenious, and, on the whole, perhaps, there is less liability to waste of steam: but we fear, that the great objection to many rotary engines, namely, the striking of the sliders, will remain here in full force.

We now come to describe the rotary, for which the inventor obtained a patent in December, 1826.

Figure 1 represents an elevation of the exterior of this rotary engine. Fig. 2 represents an end view. Fig. 3 represents a section of fig. 2. Fig. 4 a section of fig. 1. *a a*, figs. 1, 3, and 4, is the cylinder, being accurately bored in the same manner as the cylinder of other steam engines, excepting that at the two ends there is a rebate. The flanges are also turned rectangularly to the cylindric part, so as to be quite smooth and true on their faces. The lids or caps *b b*, are turned on their flanges also; they are then turned flat from *c* to *f*. At *f* they project inwards, and form the cylindric bosses *d d*, (also turned,) until they nearly meet each other in the interior of the cylinder. leaving only a space of about two inches in large engines, and a proportionably less one in smaller engines. The turned flanges of the lids being ground against the turned flanges of the cylinder, form a steam-tight joining, which is made additionally secure by the corner or angle of the lid

* Repertory of Patent Inventions, vol. iv. pp. 240-5.

(FIG. 1.)

being at the same time ground against the rebate in the cylinder. On opposite sides of the cylinder, fig. 3, there are two apertures cut quite through, of an equal breadth, and extending the lengthway of the cylinder parallel to the axis, and of such a length as to reach about three quarters of an inch over the flat parts *c f*, of the lids. Grooves of a corresponding breadth, and 3-4ths of an inch deep, are cut in the lids from *c* to *f*, in a direct line to the axis. Similar grooves, *f f*, are cut in the bosses parallel to the axis. These are about an inch deep, and of the same breadth as the former. The dimensions of these grooves will be varied, to suit the size of the engine. It

is apparent that a section from *y* to *z*, fig. 2, will pass through the centre of all these grooves. The sliders, *g g*, figs. 3 and 4, are two plates of metal, faced with a thin facing of brass or gun-metal; they are of such a thickness as to move freely in their respective grooves, of such a length as to extend from the bottom of the grooves in each lid, and of such a breadth as to reach from the outside of the cylinder to nearly the bottom of the groove *ff*. The purpose of these grooves is to form a bearance for the sliders, which being made smooth and flat, and afterwards ground into their places in the grooves, become steam tight in every part, excepting at the space left between the bosses. Now there is a central plate, *x*, (fig. 3 and 4), which is attached to, and revolves with the axis *e e*. This plate is of a thickness sufficient to occupy the space between the bosses, and is kept steam tight by the circular rings 1 1 and 2 2, (placed in recesses turned in the bosses) pressing upon each side of the plate *x*. Underneath each plate is introduced a quantity of hempen or cotton packing, which answers the double purpose of preventing the escape of the steam between the ring and its recess, and that the elasticity of the packing, by keeping the ring pressed upon the plate, prevents an escape in that direction.

To make the sliders and the central plate form a steam-tight union, small pieces of brass are screwed to the sliders, and thereby allow them to be brought into contact with the edge of the plate *x*, without permitting any part of the sliders to touch the bottom of the grooves, *ff*. At opposite points of the plate *x*, there is a small portion of the circle cut away, (see F, fig. 3); the purpose of which is, that the sliders may be moved into their places without noise, for that is produced by the striking of two substances together, and these sliders cannot strike against the bottom of the grooves, nor yet, from the external cam, against the periphery of the plate.

The boxes or cases, *i i*, 1, 2, 3 and 4, are for the reception of the sliders, when they are withdrawn from the

cylinder. Stuffing boxes, *j j*, are placed in the middle of the bonnets, through which the rods, *k k*, are worked. These rods are attached to the sliders by means of cross pieces, *b b*, fig. 3, which are dove-tailed and bolted to them: and at the outer end they are keyed to the cross heads, *m m*, 1 and 2, similarly secured to the rods, *n n n n*, which are forked at the ends nearest to the axis. A small

spindle passes through the ends of each fork, upon which run three friction sheaves, the larger ones, *o*, fig. 1, being placed between the forks, and the smaller ones *p p*, on the ends of the spindle. They are not fixed to the spindle, and therefore may revolve separately and independently of each other.

The piston consists of four pieces of brass, or gun metal, of about 2¼ inches in thickness, filed, or otherwise made perfectly smooth, and uniformly thick. Each piece is in the form of the letter L, in the interior of the piston;

and the spiral springs, acting against an abutment, force them outwards. Two plates of metal, having a facing of equal breadth to the brass, are laid on each surface of the brass pieces, and pressed on them by means of the brass bolts passing through the whole of the piston. These plates and the brass pieces being previously ground together, prevent the steam from escaping between them; and, as an additional security, there are semi-circular grooves cast in the metal plates, into which hemp or cotton is stuffed, and by pressing on the brass prevents the possibility of an escape, except at the points of union between the brass pieces. In order to make these parts tight also, small overlap pieces are sunk into the brass, about one-fourth of an inch, and as the piston wears away and widens the openings between the pieces, these still continue to cover them. Those parts of the brass, which are against the arm of the piston, are let into recesses, and hemp or cotton is placed underneath them, which prevents escape in that direction. This is called a compound compensating piston: it possesses the property of being more tight than metallic pistons are generally, by the using of both hempen and metallic packing, and also being equally free and not liable to be jammed, when heated; this latter qualification arises from making the bolts, which hold the plates together, of the same material as the wearing part, by which means the distance between the plates, when heated, is as much increased by the expansion of the bolts as the intervening pieces are expanded; consequently, they cannot be bound or jammed in their places, under any variation of temperature.

There are four valves in this engine; two of them are placed in each lid. They consist of circular brass plates, the bottom ones being cemented or otherwise fastened into a recess in the end cast for them; the upper plate is then placed above, and both being previously ground together, the steam cannot enter the cylinder, but through them; that is to say, when the holes in each plate are placed over each other, the valve is open, and when otherwise shut. A

plate covers the recesses in which the valves work, and may either be cast with the ends, or afterwards bolted and cemented to them; the spaces between the lids and the plates form circular chambers; and have each three openings; two circular ones, large enough to get readily to the valves, and a rectangular one, to which a steam pipe is attached. Bonnets cover the circular holes, which are thicker in their centres, having a cylindric hole large enough to admit smaller bonnets OO, fig. 4, to be placed therein. Spindles, previously keyed to the moving plate of the valves, are brought through OO to the exterior of the lids. These valves and the spindle are kept steam-tight by the screws of OO being turned a little round, which presses the bonnets, OO, in the first instance, upon the enlarged part of the spindle, (shown at fig. 4,) and also upon the face of the fixed valve plate. Small cranks, 88, fig. 2, are attached to the outer ends of the valve spindles, which are connected to the gear, 99. Upon this gear are fixed two friction sheaves, which being acted upon by the cam 01, at proper periods, the cranks, and consequently the valves, are alternately moved to and fro by the revolution of the axis, *e e*: one of them opening when the other is closing, and *vice versa.*

33, figs. 1 and 2, are two cams, one half of which (namely, from 4 to 5) is concentric with the axis, and the other part is the eccentric or cam part, by which the sliders are moved. The motion is produced by the eccentric part acting on the sheaves, *o o*, fig. 2, and moving them to and from the axis. The smaller sheaves, *p p*, run between guides, (see the dotted lines, fig. 72,) which preserve a vertical motion to the rods *n n*.

The holes, through which the steam escapes, and is admitted, are placed as near the slider as they can be brought, and are shown, for the purpose of illustration, as being all in one lid, at fig. 3, though, as has been previously stated, there are two in each lid. The effect, however, would be the same were they as represented in fig. 3, and therefore this mode of explanation will be as clearly understood.

A pipe is brought round, as at A, fig. 2, into a steam-chest, B, fig. 1, and 2, in which latter is a common slide valve. Into this steam-chest the steam is brought from the boiler, by the pipe C, and escapes into the atmosphere or condenser by the pipe D. This slide valve, and the apparatus connected with it, are for the purpose of reversing the motion of the engine.

In order to put this engine in operation, steam is admitted into the steam-chest B, when the slide valve is placed in such a position as to allow the steam to enter

in at one end, and escape at the other; or in other words, when the valves 6 and 7, fig. 3, are the induction valves, and 14 and 15 the eduction valves; and when the piston and sliders are in the position shown at fig. 4. The valve, 14, is then open, and communicates with the atmosphere or condenser, and the valve, 7, with the boiler; the steam, therefore, entering through 7, rushes against the piston and the upper slider, which becomes the abutment against which the steam exerts its force. The piston recedes from the pressure in the direction of the arrow, turning with it the central plate *x*, the axis, *e e*, the cams, 3, 3, and the valve cams, 01, 01. As the shaft turns, therefore, the cam 3, fig. 2, revolves, and the cam or eccentric part gradually leaves the lower rods, *n n*, and presents the *concentric* part to the sheaves of the said rods. Now the lower cross head being pressed upwards by the counterbalance, E, gradually ascends into the cylinder, so that when the point 4, is in contact with the sheaves of the lower rods *n n*, the slider has then reached its place in the cylinder, being nearly in contact with the central plate F, and also upon its bearance in the grooves before-mentioned; the piston will be then at the point G of the cylinder, and both the sliders shut, the two valves, 7 and 14, only being open. Now, as the piston continues to revolve, the cams 3 3 are gradually opening the upper slider, and the cams 10 gradually shutting the valve 14, and opening the valve 15; so that when the piston reaches the valve 15, the former is completely shut, and the latter completely open; and when the piston reaches the upper slider, it is completely withdrawn from the cylinder, and thereby allows the piston to pass it. At this point, the steam is entering through 6, and escaping through 15, the lower slider being then the abutment upon which the steam acts. After the piston has passed the upper slider, the cam 3 allows the piston gradually to return to its place in the cylinder, and after the piston has passed the valve 6, that valve begins gradually to open, and the valve 7 to close. Therefore, when the piston has reached the pipe H, the upper slider is in its seat in the cylinder, the valves 7 and 14 are quite

shut, and 6 and 15 quite open: the cam 4 then begins to give motion to the lower slider, as before described, and the cams 10 to the valves, so that a constant rotation of the axis is kept up.

To reverse the motion of this engine, the sliding valve in the steam-chest is moved on its face, so that the valves 6 and 7 become the eduction valves, and 14 and 15 the induction valves. Supposing the piston therefore in the position shewn in fig. 3, and the steam previously entering through 6 and 7, and escaping through 14, it will be seen that if 6 and 7 become the escape valves, and 14 and 15, the induction valves, the steam from the boiler will then rush through 14, and press upon the piston, and so drive it in a direction contrary to the *arrow*, whilst the steam, before actuating the engine, escapes through 6 and 7, which being shut and opened at their proper time by the cams 01, keep up the rotation in the opposite direction.

The difficulties which have been encountered in the construction of a rotary engine, have been so repeatedly enumerated in the course of this work, that it would be needless to repeat them. It will be remembered that great friction, leakage, and the difficulty of maintaining the packing steam-tight, have been generally found the great obstacle to the successful adoption of such engines. It is calculated that these objections have been removed by the author's patent engine. The friction has been reduced in a very great degree, compared to that of the reciprocating engine, the greatest being caused by the revolution of the piston and shaft. The sliders are found to cause scarcely any friction, as they are only moved, when they are surrounded on every side by the same medium; and as the grooves are sufficiently wide to allow them to move without rubbing against their sides, the only resistance is caused by the rods working through the stuffing boxes. The valves also have the advantage of being only in motion, when they are surrounded by the same medium, and consequently the wear and friction are reduced considerably below that of the slide of a common engine, which is only moved when under a pressure of steam.

The leakage is found to be considerably less than the leakage of all the engines on this principle which we have hitherto seen. This superiority arises from the use of the compound packing in the piston, by which a great defect in metallic pistons has been obviated. This defect was the difficulty of making the metallic pieces which formed the packing, of an equal thickness, and of bringing them in sufficiently close contact with the plates which enclose them: for it will be seen, that unless the whole of the metallic packing were of a uniform thickness, it would not, when moved out of the situation into which it was at first fitted, fit so closely to the covering plate, and consequently a leakage would take place. By the improved method, however, it is not necessary that the packing should be so carefully constructed, because the elasticity of the hempen packing would make up for any little irregularity in the metallic part.

The sliders are found also to be much less liable to leakage than the abutment of other rotary engines. This advantage may be attributed to the bearing in the grooves being inaccessible to the piston, or any other part of the machine, except the sliders themselves, and consequently the flat surface originally given to them, is not liable to be destroyed by wear, which is the case with those engines which have leaves or flaps, or even where there are sliders which do not rest entirely in grooves, as in the present instance. It is found also that these sliders do not wear out of form, or become leaky; because, owing to their vertical motion and the width of the grooves, they can hardly be said to touch the sides of the grooves until they are forced against them by the steam, which only happens when they are at rest.

Not the least evil with which the makers of rotary engines have had to contend, has been the rapid destruction of those parts which have struck each other. Now this is a fault that has invariably existed in all the engines with leaves or sliders. It is however here completely obviated by the mode of bringing the sliders to rest; for, instead of allowing them to strike the central plate, a cavity is

formed therein at the part where the slider would, but for that cavity, have come in contact with it. The slider therefore can neither touch the bottom of the grooves in the bosses, nor yet the central plate; the external camwork preventing it from reaching so far into the cylinder. The edge of the plate and the slider are brought into contact by the circular part of the former gradually introducing itself like a wedge under the slider after it is at rest, and consequently a stroke is avoided.

We regret to state, that notwithstanding the advantages which this engine was expected to possess, it has hitherto proved an unfortunate speculation. An engine of twelve horse power was constructed, for the purpose of working a steam boat on the river Tyne, which, while it was in operation, promised to answer all the purposes anticipated from it. That engine has been since taken out of the boat, and an engine on the reciprocating principle substituted for it. This was done whilst the inventor was in London, and he has every reason to believe that unfair means were adopted by interested parties to procure its removal. True it is, that almost every unfortunate patentee tells his story of having been injured by malicious workmen, fickle partners, or exhausted means; and it is equally true, that many instances have occurred in which meritorious inventions have failed from those causes. We however, have to state, that one part of this failure was attributable to imperfect workmanship, which, by breakage, occasioned a number of unpleasant and tedious delays, and another part to a misfortune which all experimentalists should avoid; namely, that the engine was put into a boat belonging to a party who had no interest in the success of the machine. The consequence of this arrangement was, that the delay and alterations which were necessarily attendant on a new invention, were to him a subject of serious disappointment; and therefore there is strong moral evidence to suppose that means were used of an unfair description, to obtain the removal of the engine. One unfortunate circumstance was, that the proprietor of the boat used various means

to harass the engineman (who was placed there at the request of the inventor), and subsequently induced him to abandon his charge. A person was then substituted for him, who was not only unacquainted with the principle of this engine, but who was also perfectly inexperienced in the management of any engine whatever; the result was, that for want of oiling and cleaning the joints, the exterior apparatus was in a short time so seriously injured, as to furnish a pretext for the removal of the engine from the boat.

Notwithstanding this misfortune, the inventor is firmly convinced of the superiority of his rotary engine for certain purposes, over the reciprocating principle; and in confirmation of this he has to state the fact that the piston, sliders and valves, were not in any degree injured, either by the fair working of the engine, or by the neglect and improper usage to which they were subjected. The whole of the defects lay in the exterior machinery, and principally in the workmanship of the condensing apparatus, which it is admitted was not of sufficient strength for the purpose.

SECOND SECTION.

ON STEAM NAVIGATION.

The idea of propelling vessels by the steam engine appears to have been entertained as soon as that machine had its existence. Savery, in his Miner's Friend, mentioned the possibility of propelling vessels by steam, but never attempted to carry his project into effect. After the introduction of Newcomen's engine, various attempts were made to obtain a revolving motion, by which the engine might be applied to machinery in general. These chiefly failed from defective mechanism. Among such attempts we find the invention of Mr. Jonathan Hulls, of

London, who, in 1736, took out a patent for the application of the crank to the steam engine, by which addition he purposed "to carry vessels or ships out of or into a harbour, port, or river, against wind or tide, or in a calm."

We need not say that this project was never carried into execution. The application of the crank to the single acting engine has always been found a matter of great difficulty, because as the ascending stroke has to be effected by a counter-balance, an immense fly-wheel is necessary to produce anything like regularity, and it would be absolutely impossible to use such a fly wheel in a boat. In consequence of the want of proper machinery, Hull's idea fell to the ground, and indeed was so completely forgotten, that Mr. Watt actually took out a patent for the application of the crank to the steam engine.

The perfection to which the revolving machinery was brought by Mr. Watt, and others, opened the way to the ready application of steam for the purposes of navigation, and sundry trials were made in various parts, but more particularly in Scotland, to ascertain the practicability of the project. Of these trials, little or no record remains; the earliest successful one appears to have been made on the Forth and Clyde Inland Navigation, in the year 1801, by Mr. Symington; but this steam boat, although it fully served to solve the problem, was unfortunately laid aside on account of the injury sustained by the banks of the Canal, in consequence of the waves which were raised by the stroke of the paddles.

It appears by the statement of the ingenious Mr. Oliver Evans, of America, whose engine is described at page 141, that, so early as 1785, he had published a description of a mode of driving boats by steam.

Untoward circumstances prevented Mr. Evans from carrying his plan into effect, until 1804; but he does, in our opinion, fully establish his claim to the first contrivance of a *practicable* steam boat. We shall insert Mr. Evans's own account of the commencement and progress of his ideas and experiments, as we consider them sufficiently important to merit every publicity.

"About the year 1772, being then apprenticed to a wheelwright, I laboured to discover some means of propelling land carriages, without employing animal power. All the modes that have since been tried, (so far as I have heard of them,) such as the wind, treadles with ratchet wheels, cranks, &c. to be worked by men, presented themselves to my mind; but were considered as too futile to deserve an experiment: and I concluded that such motion was impossible, for want of a suitable original power.

"But one of my brothers informing me, on a Christmas evening, that he had that day been in company with a neighbouring black smith's boy, who, for amusement, had stopped up the touch-hole of a gun-barrel, then put into it about a gill of water, and rammed down a tight wadding; after which they put the breech-end of it into the smith's fire, when it discharged itself with as loud a crack as if it had been loaded with gunpowder. It immediately occurred to me that there was a power capable of propelling any waggon, provided that I could apply it; and I set myself to work to find out the means of doing so. I laboured for some time without success; at length, a book fell into my hands, describing the old atmospheric engine. I was astonished to observe that they had so far erred as to use the steam only to form a vacuum, to apply the mere pressure of the atmosphere, instead of applying the elastic power of the steam, for original motion; a power which I supposed was irresistible. I renewed my studies with increased ardour, and soon declared that I could make steam waggons, and endeavoured to communicate my ideas to others; but, however practicable the thing appeared to me, my object only excited the ridicule of those to whom it was known. But I persevered in my belief, and confirmed it by experiments that satisfied me of its reality.

"In the year 1786, I petitioned the legislature of Pennsylvania, for the exclusive right to use my improvements in flour-mills, as also steam waggons, in that state. The committee, to whom the petition was referred, heard me very patiently, while I described the mill improvements;

but my representations concerning steam waggons made them think me insane. They, however, reported favourably respecting my improvements in the manufacture of flour; and passed an Act, granting me the exclusive use of them, as prayed for. This was in March, 1787, but no notice is taken of the steam waggons.

" A similar petition was also presented to the legislature of Maryland. Mr. Jesse Hollingsworth, from Baltimore, was one of the committee appointed to hear me, and report on the case. I candidly informed this committee of the fate of my application to the legislature of Pennsylvania, respecting the steam waggons, declaring at the same time, without the encouragement prayed for being granted to me, that I would never attempt to make them; but that, if they would secure to me the right, as requested, I would, as soon as I could, apply the principle to practice: and I explained to them the great elastic power of steam, as well as my mode of applying it to propel waggons. Mr. Hollingsworth very prudently observed, that the grant could injure no one; for he did not think that any man in the world had thought of such a thing before; he therefore wished the encouragement might be afforded, as there was a prospect that it would produce something useful. This kind of argument had the desired effect; and a favourable report was made, May 21st, 1787, granting to me, my heirs, and assigns, for 14 years, the exclusive right to make and use my improvements in flour mills, and the steam waggons, in that State. From that period I have felt myself bound in honour to the State of Maryland, to produce a steam waggon as soon as I could conveniently do it.

" In the year 1789, I paid a visit to Benjamin Chandler and Sons, clock-makers, men celebrated for their ingenuity, with a view to induce them to join me in the expense and profits of the project; I showed to them my drawings, with the plan of the engine, and explained the expansive power of steam; all of which they appeared to understand; but, fearful of the expense and difficulties attending it, declined the concern. However, they certi-

fied that I had shown them the drawings, and explained the powers of high-pressure steam, &c.

"In the same year I went to Ellicott's mills, on the Patapses, near Baltimore, for the purpose of endeavouring to persuade Messrs. Jonathan Ellicott and Brothers, and their connexions, (who were equally famous for their ingenuity,) to join me in the expense and profits of making and using steam waggons. I also showed them my drawings, and minutely explained to them the powers of steam; they appeared fully to comprehend all I said; and, in return, informed me of some experiments they themselves had made; one of which they showed me. They placed a gun-barrel, having a hollow arm, and a small hole on one side, at the end of the arm, similar to Barker's rotary tube mill: a little water being put into this barrel, and fire applied to the breech of it, the steam issued from the hole in the end of the arm with such force, as, by reaction, to cause the machine to revolve, as I judged, about one thousand times in a minute, for the space of about five minutes, and with a considerable force for so small a machine. I tarried here a few days, (May 10th and 11th, 1789,) using my best efforts to convince them of the possibility and practicability of propelling waggons, on good turnpike roads, by the elastic power of steam. But they also feared the expense and difficulty of the execution, and declined the proposition. Yet they highly esteemed my improvements in the manufacture of flour, and adopted them in their mills, as well as recommended them to others.

"In the same year I communicated my project, and explained my principles, to Levi Hollingsworth, Esq. now a merchant in Baltimore. He appeared to understand them; but also declined a partnership in the scheme, for the same reasons as the former persons.

"From the time of my discovering the principles, and the means of applying them to use, I often endeavoured to communicate them to those I believed might be interested in their application to waggons or boats; but very few could understand my explanations, and I could

find no one willing to risk the expense of the experiment.

"In the year 1785, or 1786, before I had petitioned the legislature, I fell into company with Mr. Samuel Jackson, of Redstone; and learning of him that he resided on the Western Waters, I endeavoured to impress upon his mind the great utility and high importance of steam boats to be impelled on those waters; telling him that I had discovered a steam engine so powerful, according to its weight, that it would, by means of paddle-wheels (which I described to him), readily drive a vessel against the current of those waters, with so great a speed as to be highly beneficial. Mr. Jackson proves that he understood me well; for he has lately written letters, declaring that, about twenty-six years before their date, I described to him the principles of the steam engine, which I have since put into operation to drive mills, which he has seen; and that I also explained to him *my plan for propelling boats by my steam engine with paddle-wheels, describing the very kind of wheels now used for this purpose; and that I then declared to him my intention to apply my engine to this particular object, as soon as my pecuniary circumstances would permit.*

"In the year 1800, or 1801, never having found a person willing to contribute to the expense, or even to encourage me to risk it myself, it occurred to me that, although I was then in full health, I might be suddenly carried off by the yellow fever, that had so often visited our city (Philadelphia), or by some other disease or casualty, to which all are liable; and that I had not yet discharged my debt of honour to the state of Maryland, by producing the steam waggons; I determined, therefore, to set to work the next day, to construct one. I first waited upon Robert Patterson, Esq. professor of mathematics in the university of Pennsylvania, and explained to him my principles, as I also did to Mr. Charles Taylor, steam engineer, from England. They both declared these principles to be new to them, and highly worthy of a fair experiment; advising me without delay to prove them, in hopes that I might

produce a more simple, cheap, and powerful steam engine, than any in use. These gentlemen were the only persons who had such confidence, or afforded me such advice. I also communicated my plans to B. H. Latrobe, Esq. at the same time, who publicly pronounced them chimerical, and attempted to demonstrate the absurdity of my principles, in his Report to the Philosophical Society of Pennsylvania, on steam engines; in which report he also attempts to shew the impossibility of making steam boats useful, on account of the weight of the engine, and I was one of the persons alluded to as being seized with the steam mania, in conceiving that waggons and boats could be propelled by steam engines. The liberality of the members of the society caused them to reject that part of his report which he designed to be demonstrative of the absurdity of my principles; saying, they had no right to set up their opinions as a stumbling-block in the road of any exertions to make a discovery. They said I might produce something useful, and ordered it to be struck out. What a pity they did not also reject his demonstrations respecting steam boats! for, notwithstanding them, they have run, are now running, and will run; so has my engine and all its principles succeeded; and so will land-carriages, as soon as these principles are applied to them.

"In consequence of the determination above alluded to, I hired workmen and went to work to make a steam waggon, and had made considerable progress in the undertaking, when the thought struck me, that, as my steam engine was entirely different in form, as well as in its principles, from all others in use, I could obtain a patent for it and apply it to mills, more profitably than to waggons; for, until now, I apprehended that, as steam mills had been used in England, I could only obtain a patent for waggons and boats. I stopped the work immediately, and discharged my hands, until I could arrange my engine for mills; having laid aside the steam waggon for a time of more leisure.

"Two weeks afterwards I commenced the construction of a small engine, for a mill to grind plaster of Paris.

The cylinder six inches in diameter, and the stroke of the piston eighteen inches, believing that, with one thousand dollars, I could fully try the experiment. But, before I had done with experiments, I found that I had expended three thousand seven hundred dollars—all that I could command! I had now to begin the world anew, at the age of forty-eight, with a large family to support. I had calculated that if I failed in my experiment, the credit I had acquired would be entirely lost, and, without money or credit, at my advanced age, with many heavy incumbrances, my way through life appeared dark and gloomy indeed! But I succeeded perfectly with my little engine, and preserved my credit. I could break and grind 300 bushels of plaster of Paris, or 12 tons, in twenty-four hours; and to show its operation more fully to the public, I applied it to saw stone, in Market-street, where the driving of twelve saws in heavy frames, sawing at the rate of 100 ft. of marble in twelve hours, made a great show, and excited much attention. I thought this was sufficient to convince the thousands of spectators of the utility of my discovery; but I frequently heard them inquire if the power could be applied to saw timber, as well as stone, to grind grain, propel boats, &c.; and though I answered in the affirmative, I found they still doubted. I therefore determined to apply my engine to many new uses, and to introduce it and them to the public notice.

"This experiment completely tested the correctness of my principles, agreeably to my most sanguine hopes. The power of my engine increased in a geometrical proportion, while the consumption of fuel had only an arithmetical ratio; and in such proportion that every time I added one fourth to the consumption of fuel, the power of the engine was double; and that twice the quantity of fuel required to drive one saw, would drive sixteen saws at least; for, when I drove two saws, the consumption was eight bushels of pit coal in twelve hours; but when twelve saws were driven, the consumption was not more than ten bushels; so that the more we resist the steam, the greater is the effect of the engine. On these

principles very light but powerful engines can be made, suitable for propelling boats and land carriages, without the great incumbrance of their own weight, as mentioned in Mr. Latrobe's demonstrations. In the year 1804, I constructed at my works, situated a mile and a half from the water, by order of the Board of Health of the city of Philadelphia, a machine for cleansing docks. It consisted of a large flat or lighter, with a steam engine of the power of five horses on board, to work machinery to raise the mud into lighters. This was a fine opportunity to show the public that my engine could propel both land and water-carriages, and I resolved to do it. When the work was finished, I put wheels under it, and though it was equal in weight to two hundred barrels of flour, and the wheels were fixed on wooden axle-trees for this temporary purpose in a very rough manner, and attended with great friction, of course, yet with this small engine, I transported my great burthen to the Schuylkill with ease; and when it was launched into the water, I fixed a paddle wheel at the stern, and drove it down the Schuylkill to the Delaware, and up the Delaware to the city; leaving all the vessels going up behind me, at least half way, the wind being a-head.

"Some wise men undertook to ridicule my experiment of propelling this great weight on land, because the motion was too slow to be useful. I silenced them by answering, that I would make a carriage to be propelled by steam, for a bet of three hundred dollars, to run upon a level road against the swiftest horse they could produce. I was then as confident as I am now, that such a velocity could be given to carriages.

"Having no doubt of the great utility of steam carriages on turnpike roads, with proper arrangements for supplying them with water and fuel; and believing that all turnpike companies were deeply interested in carrying them into operation, because they would smooth and mend the roads instead of injuring them, as the narrow wheels do; on the 26th of September, 1804, I submitted to the consideration of the Lancaster Turnpike Company, a

statement of the cost and profits of a steam carriage, to carry one hundred barrels of flour, fifty miles in twenty-four hours; tending to show, that one such steam carriage would make more net profits than ten waggons drawn by five horses each, on a good turnpike road; and offering to build such a carriage at a very low price. My address closed as follows:—

"'It is too much for an individual to put in operation 'every improvement which he may invent. I have no 'doubt but that my engines will propel boats against the 'current of the Mississippi, and carriages on turnpike roads 'with great profit; I now call upon those whose interest 'it is to carry this invention into effect.' In the year 1805, I published a work describing the principles of my steam engine, with directions for working it, when applied to propel boats against the current of the Mississippi and carriages on turnpike roads. And I am still willing to make a steam carriage that will run fifteen miles an hour on good level railways, on condition that I have double price if it shall run with that velocity; and nothing at all for it, if it shall not come up to that speed. What can an inventor do more, than to insure the performance of his inventions? or I will make the engine and apparatus at a fair price, and warrant its utility for the purpose of conveying heavy burthens on good turnpike roads. I feel it just to declare, that with Mr. Latrobe I myself believed, that with the ponderous and feeble steam engine now used in boats, they never could be made useful in competition with sailing boats, or to ascend the Mississippi; believing the current of that river to be more powerful than it is. But I rejoice, that with him I have been mistaken; for I have lived to see boats succeed well with those engines, and I still hope to see them so completely excelled and out-ran by using my engine, as to induce the proprietors to exchange the old for the new, more cheap, and powerful engines.

"I have been highly delighted in reading a correspondence between John Stevens, Esq. and the commissioners appointed by the legislature of New York, for fixing upon

the site of the new canal, proposed to be cut in that State. Mr. Stevens has taken a most comprehensive and very ingenious view of this important subject; and his plan of railways for the carriages to run upon, removes all the difficulties that remain to be overcome. I had the pleasure also of hearing gentlemen of the keenest penetration and of great mechanical and philosophical talents, freely give into the belief, that steam carriages will become very useful.

"Mr. John Ellicot (of John), proposed to make roads of substances, such as the best turnpike roads are made with, with a path for each wheel to run on, and having a railway on posts in the middle to guide the tongue of the waggon, and to prevent any other carriage from travelling upon it. Then, if the wheels were made broad and the paths smooth, there would be very little wear; such roads might be cheaply made, they would last a long time, and require very little repair; and they ought to be preferred in the first instance to those proposed by Mr. Stevens; as two ways could be made in some parts of the country, for the same expense as one could be made with wooden rails; but either of the modes would answer the purpose, and the carriages might travel by night as well as by day. When we reflect upon the obstinate opposition that has constantly been made by a great majority, to every step to improvement, from bad roads to turnpike roads, from turnpike roads to canals, and from canals to railways for horse carriages; it is too much to expect, that the prodigious leap from bad roads to railways for steam carriages, will be made at once; one step in a generation is all that we can hope for. If the present generation shall adopt canals, the next may try the railways with horses, and the third generation may use the steam carriages.

"But why may not the present generation, who have already good turnpike roads, make the experiment of using steam carriages upon them? They will, assuredly, effect the movement of heavy burdens, with a slow motion of two and a half miles an hour; and, as their progress

need not be interrupted, they may travel fifty or sixty miles in the twenty-four hours. This is all that I hope to see in my time; and though I never expect to be concerned in any business, requiring the regular transportation of heavy burdens on land; because, if I am connected in the affairs of a mill, it shall be driven by steam, and be placed on some navigable water, to save land carriage; yet I certainly intend, as soon as I can make it convenient, to build a steam carriage, that will run on good turnpike roads, on my own account, if no other person will engage in it; and I verily believe that the time will come when carriages, propelled by steam, will be in general use, as well for the transportation of passengers as goods; travelling at the rate of 15 miles an hour, or 300 miles a day!

"It appears necessary to give the reader some idea of the principles of the steam engine which is to produce such new and singular effects; and this I will endeavour to do in as few words as I can, by showing the extent to which the principles are already applied.

"To make steam as irresistible or powerful as gunpowder, we have only to confine it, and to increase the heat by adding fuel to the boiler. A steam engine, with a working cylinder, only nine inches in diameter, and the stroke of the piston three feet, will exert a power sufficient to lift from 3000 to 10,000 lbs. perpendicularly, two and a half miles per hour. This power, applied to propel a carriage on level roads or railways, would drive a very great weight with much velocity, before the friction upon the axletrees, or the resistance of the atmosphere would balance it.

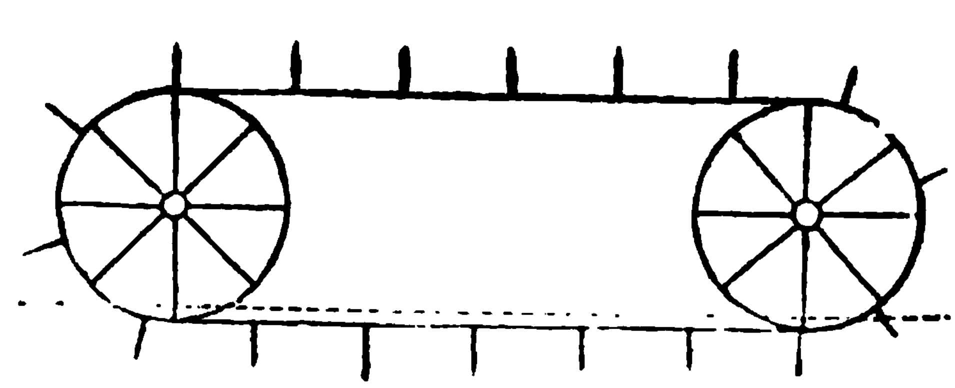
"This is not speculative theory. The principles are now in practice, driving a saw-mill, at Manchacks, on the Mississippi; two at Natchez, one of which is capable of sawing 5000 feet of boards in twelve hours; a mill at Pittsburgh, able to grind twenty bushels of grain per hour; one at Marrietta, of equal power; one at Lexington, (Kentucky,) of the same power; one a paper-mill, of the same power; one, of one fourth the power, at Pittsburgh;

one at the same place, of three and a half times the power, for a forge, and for rolling and slitting iron; one of the power of 24 horses, at Middletown, (Connecticut,) driving the machinery of a cloth manufactory; two at Philadelphia, of the power of five or six horses; and many making for different purposes; the principles applying to all cases where power is wanted to drive machinery."

No experiment of importance after Mr. Symington's, in 1801, or Mr. Evans's, in 1804, appears to have been tried either in Great Britain, or America, until the celebrated American Engineer, Mr. Robert Fulton, constructed a steam boat, which was launched at New York, on October 3d, 1807, and began to ply between New York and Albany, a distance of 144 miles. In 1812, a boat called the Comet, was tried on the Clyde. Shortly afterwards, Mr. Theodore Lawrence, of Bristol, constructed a steam boat, which he tried on the Avon, and finding it successful, proceeded with her through the canals, to the Thames; but, in consequence of some of the bye-laws of the Watermen's Company, he was prevented from using her profitably, and under the necessity of returning her to the Avon. After this, steam boats were tried on various rivers, both in England and Scotland, with different success. These were generally, as may be naturally concluded, of a very imperfect construction. The speculation being then extremely hazardous, old boats, and in some cases old engines, were adopted. The consequence of which was, the first experiments just so far proved the advantage of steam navigation, as to warrant other parties to construct superior vessels and engines, and thereby reap the profit.

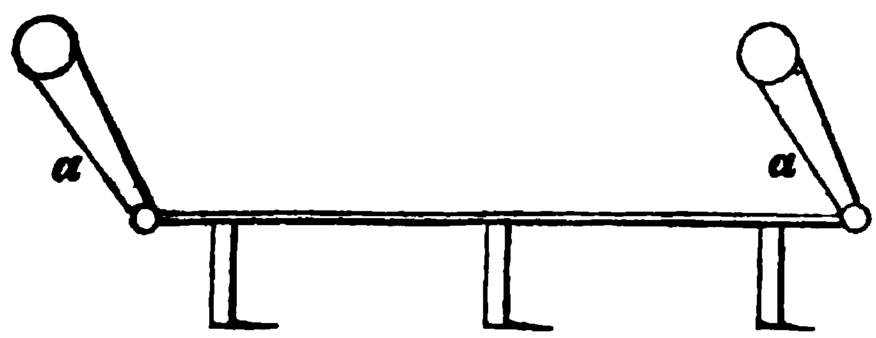
The construction of the engines resembled each other pretty nearly, in the last experiments; they being generally beam engines, the beam working above the deck, and having an erection for the purpose of covering the machinery, which was of necessity above the level of the deck. The main difference appears to have been in the mode of applying the force of the engine on the water. The common oar, although the best application of power, where it can be instantly removed when necessary, could not, from the

great breadth which it would occupy, be used in a steam vessel. For this reason we find that a variety of plans have been published for effecting this object. One method was by a species of folding oar, which opened outward, when it was moved towards the stern, but which folded into a smaller space by the reversed motion; also by a species of screw, which being entirely immersed in water, raised the water and discharged it behind the stern. These, and a variety of other plans, however, were all found inferior to the common paddle wheel, which (on account of the simple mode by which it may be attached to the machinery, as well as its combining strength and compactness,) is now universally preferred for giving motion to steam vessels. A variety of modifications have been tried, by which the loss arising from the *back water* (that is, the water which is lifted as the paddles rise,) could be avoided. We shall offer no apology for inserting some of the methods by which this difficulty has been proposed to be remedied. A trial was made in America, of a species of screw, which was placed at the head or stern of the vessel, and completely immersed in water, the spindle extending in the line of the vessel; this was, after a considerable trial, laid aside; but the reasons of its failure we cannot ascertain. It appears probable, that if the screw were constructed with only one revolution, that it might be applied in small boats with advantage. Various attempts have likewise been made to give motion to the boat by means of paddles attached to chains, which pass over two drums placed on the sides of a vessel, as represented in the drawing, by which it was expected, that the effect would be considerably increased by the number of paddles which were acting upon



the water at the same time. It was however found on trial that the great friction of the chains, together with the number of parts, which were exposed to injury, prevented their successful adoption.

Another method, upon a somewhat similar principle, is represented in the accompanying figure. The cranks *a a*, are

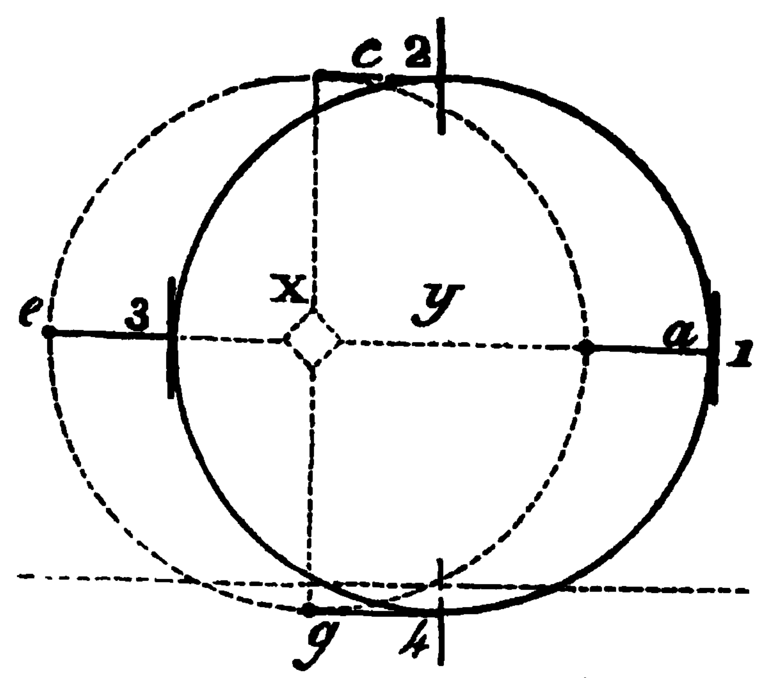


moved by the engine, and turn with them the horizontal bar, to which are fixed the vertical paddles. By this method, all the paddles are immersed in the water in a vertical position, and raised out of it, in the like manner; but although the back water is avoided by this method, yet it is obvious that another difficulty is encountered, of a more formidable nature; which is, that the motion of the paddles in entering, is exceedingly slow, and probably slower than the speed at which the vessel passes through the water; so that, unless the speed be too great, when the paddles move at their greatest velocity, namely, when the cranks are vertical, they must at entering, and leaving the water, considerably impede the motion of the boat.

A method of keeping the paddles vertical, during the revolution, is described by Mr. Robertson Buchanan, in his "Treatise on propelling vessels by steam," which he thus explains.

"If two equal rings or circular lines in the same plane, or in planes parallel to each other, be conceived to revolve each upon its respective centre in its own plane, with one and the same uniform velocity, and in the same direction with regard to parts of the rings, or lines alike situated, and anv point be taken in one of the lines or rings, and a right line be drawn from that point, parallel to a line supposed to join the centres, until it meets the other ring or circle, then the right line so drawn, will be equal to

the line of distance between the centres, and will continue equal and parallel to that line of distance, during the whole of every revolution so made."



The dotted circle and the black circle in the accompanying figure, denote the rings or circles mentioned in the theorem, and Y and X denote their centres; and the lines 1 *a*, parallel to and equal to X Y, the line of distance of the centres, will continue equal and parallel to that line of distance, in the positions 2 *c*, and 3 *e*, and 4 *g*, and in all other positions into which the point 1, can be brought, during the uniform, equal and similarly directed revolutions of the two circles.

It will be evident upon a little inspection, that this paddle wheel of Mr. Buchanan's is liable to the objections stated to exist against the last-described apparatus, namely, that of impeding the speed of the boat, by its comparatively slow motion, on entering and leaving the water. This fault, together with that of great complexity, and consequent liability to breakage, must we fear preclude its successful adoption.

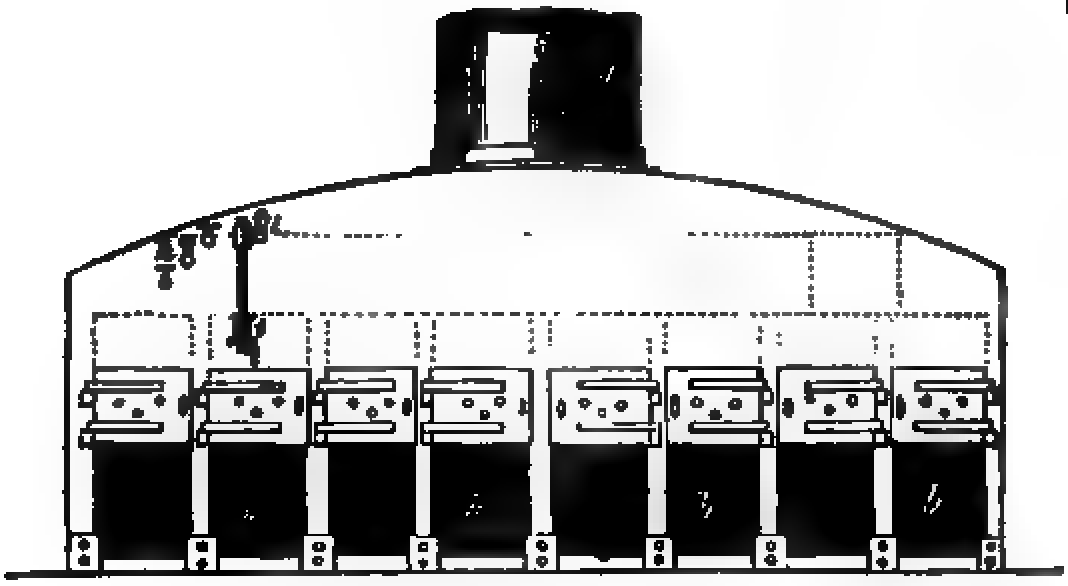
After the great number of attempts to improve the construction of the paddle-wheel, it is with some degree of hesitation that we submit a project of our own, which, we cannot help thinking, will retain all the advantages of the present paddle, and at the same time considerably reduce the quantity of back water.

The principle may be thus explained :—the paddle wheel is composed of wrought iron hoops and arms, in the usual manner; the paddle, instead of extending the whole breadth of the wheel, is divided into three pieces, which are attached to cross bars, not in the same line, but the two exterior pieces placed a little behind the middle piece. It will be seen that such a paddle will, when immersed in the water, produce nearly the same effect as if it were all in one piece; because the same quantity of surface is in both acting upon the water, but in rising out of the water it will be evident that much greater facility is afforded by the divided paddle for the water to run off, and consequently the wheel will be divested of a considerable portion of its back water.

The United Kingdom Steam Packet is one of the largest which has been erected in this kingdom, and is of 1000 tons burthen. She plies regularly between London and Leith, performing the voyage in from 40 to 50 hours. She measures 148 feet in the keel, and the breadth of her beam is 45 feet. The accommodations for passengers are of the most elegant and convenient description. She is propelled by two engines of 100 horse power each, (constructed by Mr. Napier, of Glasgow) which are considered as specimens of very superior workmanship. As these sorts of engines very nearly resemble each other, we have selected those of this vessel as illustrations of the mode in which steam boat engines are constructed.

The boiler, figs. 3, 4, and 5, which is of wrought iron, is 25 feet 6 inches in length, 19 feet in breadth, and 8 feet 6 inches in height. There are eight rectangular tubes *b b*, running the lengthway of the boiler. The fire is placed in the upper part of each of these, upon the bars *c*, in the section. At the farther end of the tubes is a transverse one *d*, extending the whole breadth of the boiler, which communicates with every one of the tubes, containing the fire, at each end of *d*. On the top, a return tube *e e*, carries off the smoke and fire into another transverse tube *f*, out of the centre of which the chimney *g* rises. The cocks *h h h* are for ascertaining the height of water in the

FIG. 3



boiler; but in this boiler a very ingenious mode is used, by which the necessity of the cocks *h* is dispensed with. There are two cocks *i i*, which are placed the one considerably above, and the other as much below, the assumed level of the water; these cocks communicate with a vertical tube of glass *j*, of sufficient strength to endure the force of the steam. On the cocks *i i*, being opened, water enters into the lower cock, and steam into the upper one, and the pressure being the same in the boiler, the water stands at the same level, and thereby indicates at all times whether it be too high or too low, in the boiler.

In the subjoined engraving, fig. 1, represents an end view of the two engines, and fig. 2, a side view of one of them. The letters refer to the same parts in each. The cylinders *a a*, are of cast iron, and fixed to a framing, which is bolted to the bottom of the boat. The piston rods *b b*, are keyed at the upper ends, to the cross heads *c c*, to the exterior ends of which are attached the connecting rods *d d*. The lower ends of these connecting rods are inserted in the forked end of the beams *e e*, which vibrate upon a shaft *f*, the bearances of which rest upon the top of the condenser *g*. In the same forks are inserted the ends of other connecting rods *h h*, which are keyed at their upper ends to cross heads *i i*. In the centre of these cross-heads are bushes large enough to receive the rods *j j*, which extend to the crank pins of the cranks *k k*. These cranks are fixed to the main shaft, which rests upon the bearances *l l*, upon the arches *m*, which are bolted to the cross beam, as at *n*. The shafts are shewn as broken off at the outer ends, but they extend to the outside of the paddle wheel.

The side beams *e e*, are not straight, but have two bends, represented by the lighter parts of the shading, the ends near the cylinder being therefore much farther apart than the opposite ends, so that they may take up as little room as possible, by laying close to the respective parts of the machinery. They are also forked at the end nearest the air pump *o*, so as to admit the insertion of the pump rods *p*, which are connected at their upper ends to the cross-head *q*, in a bush, in the centre of which is keyed the

air-pump rod *r*. Connecting rods *s*, are attached at *t*, to the side beams *e*, and at their upper ends to cross-heads, which are connected as at *u u* (fig. 1) to two rods, which work the plungers of two feed pumps *v*, for supplying the boiler.

j is the apparatus for blowing through, previous to starting the engine. It consists of a cock, which opens or closes a communication between the steam chest and condenser, by turning the handle.

The rod and lever *x*, are for the purpose of regulating the quantity of injection water, which enters into the condenser, by a pipe from the outside of the vessel, and can be increased and lessened in quantity, by turning a cock, to which the rod *x* is attached. *y* is the hot well, into which the condensing water is discharged from the air pump. The feed pumps are supplied with water from this hot well, through the medium of a pipe, the overplus being discharged through the side of the vessel, by another pipe which is not seen.

In the steam chest 1, is contained the sliding valve. For the purpose of explaining its principle, we shall here introduce a separate diagram, which may be taken as a representation of the best form in which it is constructed, though it varies somewhat in its relative position from that of the engine we now describe. The cylinder *a* in the following figure has two apertures *b c*, at top and bottom, to which are bolted and cemented the upright pipe *d*, having near its centre, or in any other convenient part, a broad face represented at *e*, in which are three oblong holes, the upper one running into the cylinder, through *b*, and the lower one into the cylinder through *c*. The middle one communicates with a separate recess *h*, to which is attached a pipe, which forms a communication with the condenser. The steam chest *f*, is a rectangular box of cast iron, and has a pipe attached to it from the boiler; this chest is covered over, and made steam-tight by a lid *g* screwed to it. On the upper side of the steam chest is a stuffing box, through which passes a turned rod for working the sliding valve *k*, which is represented in section.

This valve has a flat face, neatly ground to the surface *e*, sufficient to cover two of the holes of *e*, and twice the breadth of any one of the surfaces intervening between any of the holes in *e*. The valve is raised into a box, from its open interior part, being of sufficient dimensions to cover, as in its present situation, two of the passages *e*, and leave open a third, the bottom one in the present instance being open.

If steam were admitted into the steam chest, whilst the valve was in its present position, it could only enter into the cylinder through *c*, and consequently would cause the piston to ascend, whilst the air above it would be discharged through *b*, and the open part of the valve, and so into the condenser; but suppose that the valve be depressed so as to cover the middle and lowest holes, then the steam from the boiler would have free communication with the upper side of the piston, through *b*, which it would consequently force downwards, whilst the steam used in the

ascending stroke would be discharged into the condenser, through the interior of the sliding valve; so that by changing the situation of the valve, the piston may be made to ascend or descend at pleasure.

The mode by which the valves in the engine beforementioned are worked, is by eccentrics on the main shaft, which work cranks; a spindle extends across between the supporting columns, in the centre of which is another crank, which gives motion to a slide rod, through the medium of two other rods.

The piston rods and cross-heads preserve their vertical motion, by horizontal bars, having adjustable brasses on their outer ends, fitted to the columns, upon which they work smoothly up and down.

The framing of the two engines is bound together by eight bars meeting together in the ball 10, upon the top of which is fixed a lamp 11.

It appears that 20 cwt. of Weyms Coal, per hour, are necessary to keep this engine going, and consequently her average consumption is about 45 tons for each voyage.

It appears that the Americans have brought steam navigation nearer to a state of perfection than ourselves, not only in their machinery, but in the style of fitting-up, and the accommodations for passengers. By a private letter from America, we are informed that "The Independence Steam Boat has run between New York and Albany, a distance of 144 miles, in 11¼ hours. The New Philadelphia has performed the same voyage frequently, in 11 hours and 50 minutes. They start at six o'clock in the morning, and sail up the Hudson River, landing passengers in Albany (after stopping at ten or twelve places) at six in the evening. The accommodations are superb, and the provisions such as to gratify an epicure; the dining room of the North America is about 150 feet in length; she will dine from 700 to 1000 passengers. The floors are covered with the most elegant Brussels carpet. The curtains are of silk damask, the ornamental work richly carved; the room decorated with works of celebrated artists. The fare, including three meals, is only four dollars."

THIRD SECTION.

ON STEAM CARRIAGES.

CERTAIN problems have been entertained regarding the power of the steam engine, which have been coeval with its existence. We have seen its earliest inventor anticipating its application to the driving of vessels at sea, and we also find its great improver calculating, with certainty, on its capability of propelling carriages on the land. As far as the bare discovery goes, Savery and Watt are the parties to whom the credit of being the inventor of each of these curious applications of steam should be awarded; only that by such an award we should dispense an equal praise to the dreamer, who has also built his castles in the air, and anticipated that we should navigate it, with the same ease that we now traverse the water; because, at the time when each of these projects were suggested, the difficulties against their execution were as many, and apparently as insurmountable. Mr. Savery merely hints that "his engine might be very useful in ships, but that he dares not meddle with the matter; and leaves it to the judgment of those who are the best judges of *maritian* affairs." Mr. Watt only mentions, in one of his specifications, that his engine was applicable to the purposes of loco-motion. But Mr. Watt's project was published at a time when his engine was quite incapable of effecting this end, being encumbered with an enormous mass of heavy machinery, and when he entertained a perfect horror at working his engines without a condenser. We have seen that great, if not insurmountable difficulties are overcome by the simple apparatus of a high-pressure engine; but how a condensing engine would have succeeded, when encumbered with its load of condensing apparatus and water, requires no very extraordinary discernment to discover.

Notwithstanding the impracticability of his plan, at that time of day, Mr. Watt is described as the inventor of

the steam carriage; and the decision would have been the same, had Mr. Watt never published one single idea beyond that relating to travelling by steam; for this has ever been the way of the world! An obscure projector mentions the possibility of effecting an important improvement in art—he, with his project, perishes, and is forgotten. In the course of time, a mighty genius rises, the Newton of his day, and boldly vanquishes the difficulties from which his predecessors have shrunk, and brings the desired object into successful operation. The world wonders at the discovery; and is surprised that so simple a thing has never been conceived before. It inquires whether no previous attempts have been made at so beneficial a speculation, and in this inquiry, the worm-eaten pamphlet of the projector is handed from the shelves of the curious, and the well-earned wreath is wrested from the brow of him, who, by sacrifice and perseverance, has attained this object, to be placed on his, who never went one step in its prosecution. This has been the case in every branch of science and art, where human genius could be exerted, but in the steam engine more particularly so. Scarcely had Mr. Savery succeeded in constructing his engine, than forthwith it is discovered that it is a mere copy of the Marquess of Worcester's, and that he (Savery), forsooth, had bought up and burnt, for the better concealment of the fact, every copy of that book of quackery and folly, "*The Century of Inventions.*" This had hardly been settled, before the merit awarded to the Marquess is disputed by twenty competitors, and the laurel, which should have remained with Savery, is torn in pieces in the dispute. These and innumerable instances may be given of the unjust decisions of society, and in consequence there has not been one meritorious application of steam, the invention of which has not been contended for. The reason is this, that the mere observer does not distinguish the wide difference between merely guessing at what *may be done*, and what, by patient perseverance and immense expenditure, has been actually effected. In mechanics, as in poetry, there is no such thing as a new idea. In both, it is the arrangement, and the

novelty of combination, in which the merit consists;—the turning of the commonest and most ordinary materials to a new and beneficial purpose.

We are willing, therefore, to give Mr. Watt the credit of having first *suggested* a steam carriage, but nothing more. We have had occasion to regret, in the course of this work, that the brilliancy of that gentleman's otherwise splendid career, has been somewhat eclipsed by a studied obscurity, and in many cases an unjust monopoly. This is not only inconsistent with the innate honesty of true genius, but was in his case unnecessary and injurious. The talents of Mr. Watt needed not such a protection; the wonderful powers of his mind enabled him, in every branch of his profession, to outstrip all his cotemporaries; and that law which stipulates that a man shall fully publish his invention, in return for a limited monopoly, might have been in justice to himself complied with, to the letter.

An instance we shall give of Mr. Watt's feeling on this subject. Mr. Matthew Murray, of Leeds, made some most important improvements in the steam engine; among other things, the sliding valve, which is allowed to be one of the most valuable additions to the steam engine, and now in common use. These were admitted by Mr. Watt to be valuable improvements; but, because some of the combinations of Mr. Murray's engines, bore a trifling resemblance to the engine which was professed to be described in the obscure patent of 1768, (which has been generally allowed to explain nothing,) Mr. Watt obtained a writ of *scire facias*, by which Mr. Murray's patent was set aside.

It was probably from the same disposition to monopoly that we find almost every possible application of the steam engine claimed in the specifications of Mr. Watt. The high-pressure engine, the application of oils, fats, resinous bodies, quicksilver, &c. &c. to the piston; regulators out of number, governors, cranks, many rotary engines, together with steam carriages, and a variety of other modifications of the engine; few of which, we venture to say, are sufficiently intelligible to enable others to construct them according to the intention of the Patentee.

We have made these remarks in this place, in order to set at rest the title of Mr. Watt to the invention of steam carriages. And taking for our rule, that the party who first attempted to put them in practice, by mechanical arrangements of his own, is entitled to the reputation of being their inventor—Mr. Oliver Evans, of America, (named in the preceding section, as one of the earliest promoters of steam navigation,) appears to us to be the person to whom that honour is due.

The particulars of Mr. Evans's experiments are extremely interesting, and explain, with much clearness and evident sincerity, the circumstances which led to the prosecution of his scheme, which was carried into effect in the year 1804.

Messrs. Trevithick and Vivian's patent of 1802, describes a steam carriage, for the purpose of travelling on the common road. The carriage resembles in form the common stage-coach; an iron frame, containing the boiler and cylinder, is placed behind the carriage; the cylinder is likewise horizontal. Our readers will readily see the application of the apparatus to the wheels by a cranked axle. On both ends of the axle, cog-wheels are fixed, by which means, when the axle is made to revolve, it communicates its motion to the hinder and larger wheels of the carriage. The machine has a fly-wheel, to preserve the regularity of the motion: means are also provided for throwing any of the wheels out of gear, by which a turn can be made without difficulty.

This engine was not put into operation until 1805, when Mr. Trevithick had an opportunity of proving its utility upon the Merthyr Tydvil Rail-road, South Wales. The engine had a cylinder of 8 inches diameter, and a stroke of 4 ft. 6 inc. in length, and drew after it upon the rail-road as many carriages as carried ten tons of bar iron, from a distance of nine miles, which it performed without any supply of water to that contained in the boiler at the time of setting out, travelling at the rate of five miles an hour.

It appears that the more general adoption of this

machine was prevented by a fear that the wheels would not adhere sufficiently to the surface over which it passed, but that they would slip round without producing loco-motion, when any considerable load was attached to the machine. To obviate this *imagined* difficulty, Mr. Blenkinsop, of Middleton Colliery, near Leeds, obtained a patent, in 1811, for the application of a rack or toothed rail, laid down on one side of the railway from end to end. Into this rack a toothed wheel is worked by the steam engine: the revolution of which wheel produces the necessary motion, without any of the *slipping* alluded to.

The accompanying figure will convey to our readers an idea of Mr. Blenkinsop's plan. The boiler *x* is placed on a wooden or cast-iron frame *y*. Through its interior passes a wrought-iron tube of sufficient diameter to hold the fire and grate; this tube is carried out at the farther end of the boiler, when it is bent upwards and continued sufficiently high to form the chimney *z*. *a a* are two

(*Blenkinsop's Railway Carriage*, 1811.)

working cylinders fixed in the boiler, and which work in the usual way; the piston rods are connected by cross heads to the connecting rods *b b*. These connecting rods are brought down on each side of the boiler, and there joined to the cranks *c c*, (there being corresponding cranks on the other side of the machine) which are placed at right angles to each other, consequently the two cranks on the first shaft are horizontal and at their greatest power, at the time the other two are passing the centre. Upon these shafts are fixed (under the boiler) two small toothed wheels, which give motion to a larger toothed wheel *e*, fixed upon a third axle. A toothed wheel, *f*, is firmly keyed to the end of the central axle, and revolves with the wheel *e*. The teeth of *f* correspond with, and work into a rack, R R, stretched along one side of the railway. Motion, therefore, is given by the pistons to the wheels *d d*, which they communicate to the wheel *f* by *e:* a progressive movement is given to the carriage by the teeth of *f* taking hold of the rack.

By this means the load can be drawn up a greater acclivity than by the machine of Messrs. Trevithick and Vivian, the only objection being that the power is applied on one side only, which must have a tendency to force the flanges or projecting rims of the supporting wheels, against the edges of the rails, by which an extra friction would be produced. This, however, is a trifling inconvenience, and is not found in practice to deduct much from the effect of the engines, several of which have, since the date of the patent, been in constant use in drawing coal waggons between Middleton Colliery and Leeds.

In the year 1813, Mr. William Brunton, of Butterly Iron Works, also obtained a patent for a mode of giving motion to carriages by a very novel contrivance.

The present engraving represents this Loco-motive Engine, which he terms his "*mechanical traveller.*" "The boiler was nearly similar to that of Mr. Blenkinsop's semi-circular (*circular*); there was a tube passing through it, to contain the fuel." The cylinder A was placed on one side of the boiler; the piston-rod is projected out

behind horizontally, and is attached to the leg *a b*, at *a*, and to the reciprocating lever *a c*, which is fixed at *c*; at the lower extremity of the leg *a b*, feet are attached by a joint at *b*; these feet lay a firmer hold upon the ground, being furnished with short prongs, which prevent them from slipping, and are sufficiently broad to prevent their injuring the road.

(*Brunton's "Mechanical Traveller,"* 1813.)

On inspecting the drawing, it will be seen, that when the piston-rod is projected out from the cylinder, it will tend to push the end of the lever or leg *a* from it, in a direction parallel to the line of the cylinder; but as the leg *a b* is prevented from moving backwards, by the end *b* being firmly fixed upon the ground, the re-action is thrown upon the carriage, and a progressive motion given to it, and this will be continued to the end of the stroke. Upon the reciprocating line *a c* is fixed at 1, a rod, 1, 2, 3, sliding horizontally backwards and forwards upon the top of the boiler; from 2 to 3 it is furnished with teeth, which work into a cog-wheel, lying horizontally; on the opposite side of this cog-wheel a sliding rack is fixed, similar to 1, 2, 3, which, as the cog-wheel is turned round by the sliding rack, 2, 3 is also moved backwards and forwards. The end of this sliding rod is fixed upon the reciprocating

lever *d c*, of the leg *d e*, at 4. When, therefore, the sliding rack is moved forwards in the direction 3, 2, 1, by the progressive motion of the engine, the opposite rod, 4, is moved in the contrary direction, and the leg *d e* is thereby drawn towards the engine; and, when the piston rod is at the farthest extremity of the stroke, the leg *d e* will be brought close to the engine; the piston is then made to return in the opposite direction, moving with it the leg *a b*, and also the sliding rack 1, 2, 3; the sliding rack acting on the toothed wheel, causes the other sliding rod to move in the contrary direction, and with it the leg *d e*. Whenever, therefore, the piston is at the extremity of the stroke, and one of the legs is no longer of use to propel the engine forward, the other, immediately on the motion of the piston being changed, is ready in its turn, to act as a fulcrum or abutment for the action of the moving power, to secure the continual progressive motion of the engine.

The feet are raised from the ground during the return of the legs towards the engine, by straps of leather or rope fastened to the legs at *f f*, passing over friction sheeves, moveable in one direction only, by a ratchet and catch, worked by the motion of the engine. The feet are described of various forms in the specification, the great object being to prevent them from injuring the road, and to obtain a firm footing, that no jerks should take place at the return of the stroke, when the action of the engine came upon them; for this purpose they were made broad, with short spikes to lay hold of the ground.*

The next attempt we find to produce a loco-motive steam engine is in the patent of Messrs. Dodd and Stephenson, of Newcastle upon Tyne. The patent was dated February 28, 1815, and consisted of the application of a pin upon one of the spokes of the wheels that supported the engine, by which it travelled upon the rail-road, the lower end of the connecting rod being attached to it by what is termed a ball and socket joint; the other end of the connecting rod being attached to the cross-beam, worked up and down by the piston.

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* Wood on Rail-roads.

a b represents the connecting rod, the end *a* attached to the cross-beam, and the end *b* to one of the spokes of the wheel; in like manner the end *d*, of the connecting rod *c d*, is attached to the beam of the other piston, and *h* and *c* to a pin fixed in the spokes of the wheel B. By these means, the reciprocating motion of the piston and connecting rod is converted, by the pin upon the spokes acting as a crank, into a rotary motion, and the continuation of this motion secured by the one pin or crank being kept at right angles to the other, as shewn in the drawing.

To effect this, the patentees had two methods; to crank the axle on which each of the wheels were fixed, with a connecting rod between, to keep them always at the angle, with respect to each other; or to use a peculiar sort of endless chain, passing over a toothed wheel on each axle. This endless chain consisted at first of one broad and two

(*Losh & Stephenson's Carriage.* 1815.)

narrow links, alternately fastened together at the ends with bolts; the two narrow links were always on the outside of the broad link; consequently, the distance they were separated laterally would be equal to the breadth of the broad link, which was generally about two inches, and their length three inches. The periphery of the wheels fixed upon the axles of the engine, were furnished with cogs, projecting from the rim of the wheels, (otherwise perfectly circular and flat) about an inch or one and a half inch. When the wheel turned round, these projecting cogs entered between the two narrow links, having a broad link between every two cogs, resting on the rim of the wheel; these cogs, or projections, caused the chain to move round with the wheel, and completely prevented it from slipping round upon the rim. When, therefore, this chain was laid upon the two toothed wheels, one wheel could not be moved round without the other moving round with it; and thus secured the proper angles to the two cranks.

This mode of communicating the action of the engine, from one wheel to another, is shown in the drawing; the wheels A and B having each projecting cog-wheels, round which the endless chain passes. This contrivance entirely superseded the use of the cog-wheels, and were without the jolts or jerks incident to them; for, when the chain got worn by frequent use, or was stretched, so as to become too long, one of the chains of the axles could be moved back to tighten it again, until a link could be taken out, when the chain was moved back again to its former situation.

It will be seen from this description that Messrs. Dodd and Co.'s improvement consisted, therefore, of a renovation of Trevithick's plan of propulsion by the mere friction produced by the contact of the wheel and rail. The only material difference between the two plans being in the using of two cylinders instead of one, and in the method of connecting the axles so as to cause the cranks to continue working at right angles to each other. The purpose of this, it will be understood, was, that when the

one crank was what is called passing the centre, the other was at its greatest power, and consequently aided the former in its revolution, when for want of a fly-wheel it would have to stop in that situation. It would appear however that this plan was found insufficient to produce a proper effect, for we find that Mr. Stephenson, in conjunction with Mr. Losh, procured a second patent in 1816, for some improvements upon it. These improvements consisted in the application of steam cylinders placed under the boiler and upon the axles of the wheels: into which were inserted pistons, the rods of which were attached to bearings wherein the axles worked. These pistons being acted upon by the steam in the boiler, performed the part of springs, and served the double purpose of keeping all the wheels pressed upon the rails, (when, owing to any undulations, there would otherwise have been a tendency in the carriage to have rested only on three, or perhaps in some instances on but two of the wheels,) and of preventing any material injury to the machinery by jolts. The drawing which we use for explanation is the same as Dodd and Co.'s, and shews six wheels, but by trial it has been found that four were quite sufficient.

The patentees state, that—"in what relates to the loco-motive engines, our invention consists in sustaining the weight, or a proportion of the weight of the engine upon pistons, moveable within cylinders, into which the steam or water of the boiler is allowed to enter, in order to press upon such pistons; and which pistons are, by the intervention of certain levers and connecting rods, or by any other effective contrivance, made to bear upon the axles of the wheels of the carriage, upon which the engine rests."

e e e shew the cylinders placed within the boiler, one side of which, in the drawing, is supposed to be removed, to expose them to view. They are screwed by flanges to one side of the boiler, and project within it a few inches; and are open at the top, to the steam or water in the boiler; *g g g* are solid pistons, filling the interior of the

cylinders, and packed in the common way to render them steam-tight. The cylinders in the figure are drawn as cut through the middle to shew the pistons. The cylinder is also opened at the bottom, and is screwed upon the frame of the engine, as represented at *a a*, fig. 2. The pistons are furnished with a rod, in a similar way to other pistons, inverted and securely fixed to it; the lower end of which passes through a hole in the frame which supports the engine, and presses upon the chair which rests on the axis of the wheels on which the carriage moves. The chair has liberty to move up and down with the piston rod. When, therefore, the steam presses upon the piston, the weight is transmitted to the axle by the piston rod, and the re-action of that pressure takes as much weight off the engine. If, therefore, the cylinders be ot sufficient area, so that the pressure of the steam upon the whole of the piston be equal to the weight of the engine, the engine will be lifted up, as it were, or entirely supported by the steam, which thus forms a kind of spring of the nicest elasticity.

These loco-motive engines have been long in use at Killingworth colliery, near Newcastle, and at Hetton Colliery, on the Wear, so that their advantages and defects have been sufficiently submitted to the test of experiment; and it appears that, notwithstanding the great exertions on the part of the inventor, Mr. Stephenson, to bring them into use on the different rail-roads, now either constructing or in agitation, it has been the opinion of several able engineers, that they do not possess those advantages which the inventor had anticipated; indeed, there cannot be a better proof of the doubt entertained regarding their utility than the fact, that it has been determined that no loco-motive engines shall be used in the projected railroad between Newcastle and Carlisle, since, had their advantages been very apparent, the persons living immediately on the spot in which they are used, namely, Newcastle, would have been acquainted therewith.

The principal objections appear to be the difficulty of surmounting even the slightest ascent; for it has been

found that a rise of only one-eighth of an inch in a yard, or 18 feet in a mile, retards the speed of one of these engines in a very great degree; so much so, indeed, that it has been considered necessary, in some parts where they are used, to aid their ascent with their load by fixed engines, which drag them forward by means of ropes coiling round a drum. The steam cylinders below the boiler, which *constituted* the patent, were found very defective, for, in the ascending stroke of the working piston, they were forced inwards by the connecting rod pulling at the wheel in turning it round, and in the descending stroke the same pistons were forced as much outwards; this motion or play rendered it necessary to increase the length of the working cylinders as much as there was play in the lower ones, to avoid the danger of breaking or seriously injuring the top and bottom of the former by the striking of the piston, when it is forced too much up or down. As our meaning may not be fully comprehended without elucidation, let us imagine the cylinder of a common beam engine to be set upon springs, which have a play of one foot: the weight of the cylinder, when at rest, depresses the spring six inches, but if the engine be put in motion, *then* as the piston ascends and gives motion to the machinery, the springs below the cylinder being, as it were, the abutment upon which the steam acts, are forced downwards against their seat, with precisely the force that the piston exerts in overcoming the resistance of the machinery. In like manner when the piston descends, as much weight or pressure will be taken off these springs by the same means. The cylinder would, therefore, vibrate or dance upon the bearing springs; and, as the motion which it thus obtains is the reverse of the motion then given to the piston, the length of the cylinder should be lengthened to allow for the extreme vibration to which it is liable. A quantity of steam would therefore be lost in filling up this extra length of the cylinder at each stroke. This would also happen if the cylinder were *fixed* as usual, and the carriages of the crank and fly wheel supported upon springs, and this arrangement would then be exactly the same in prin-

ciple and effect as the parts of the loco-motive engine to which we now allude.

Several patents have likewise been obtained for loco-motive engines, applicable to the common roads, namely, that of Mr. Julius Griffith, in 1821; of Mr. Samuel Brown, in 1823; of Mr. James, in the same year; of Mr. W. H. James, in 1824; and Mr. D. Gordon, in the same year.

The only two machines which have had any thing like a trial, appear to be those of Mr. Goldsworthy Gurney, and of Messrs. Burstall and Hill, both patented in 1826.

The propelling apparatus of Mr. Gurney's engine combines the principle of Mr. Trevithick's engine, with that of Mr. Brunton's; namely, Mr. Trevithick's, in its being moved by the adhesion between the wheel and the surface of the ground; and Mr. Brunton's, in its being aided in the ascending parts of the road by a species of legs or crutches, which can be called into operation at the will of the guide.*

Mr. Gordon's patent consists in attaching a continuous series of propellers to revolving cranks, instead of only a pair with a reciprocating parallel motion, as used by Brunton.†

Messrs. Burstall and Hill's engine is upon the principle of Mr. Trevithick's, that is, it is propelled by the adhesion between the wheel and the surface of the ground.‡

There are engines on both these principles, namely, those with the propellers, and on Mr. Trevithick's plan, in successful operation; we allude to Mr. Blenkinsop's, at Middleton Colliery, and Messrs. Losh and Stephenson's, at Killingworth, Hetton, and other Collieries; and on the Stockton and Darlington Railway. The advantage which the propelling apparatus possesses over the machines which are driven by the contact only, are, that on a railway they are able to surmount a greater ascent. But it does not follow on this account that such a propelling apparatus will be found advantageous in travelling on the common roads, because a railway being a smooth

* Described in Appendix. † Ditto. ‡ Ditto.

and polished surface, does not afford such a resistance against the slipping round of the wheels as a common road. Propellers, therefore, either by cog-wheels and racks, or by the legs used in Mr. Brunton's apparatus, seem to be the only means afforded for ascending a hill, whose ascent exceeds 18 feet per mile; and as the load is carried on the rails alone, tearing up the intervening surface of ground cannot occasion any serious injury. But we do not possess the advantage on a common road, because, as every part of that is used by the vehicles of all descriptions, which successively pass over its surface, it is absolutely necessary to preserve every inch of it as level as possible. Now, such a level as this, we fear, can never be preserved in roads subject to the action of propellers, and especially on those parts of them, which, above all others, require to be kept perfectly level, *viz.* the steepest ascents. It then becomes a question, whether or not a steam carriage is capable of ascending all the ordinary hills of a road, without the aid of the propelling legs. Experiments forbid us to entertain this opinion, because, on such hills, Mr. Gurney has found it always necessary to put his propelling legs into action.

The argument which is used against our opinion, that the roads will be injured by the use of the propellers, is that they resemble in their action a horse's foot, from which it is evident that the roads sustain little injury; but there is a wide difference between the action of a horse's foot, and the propellers; the moment a horse's foot is placed on the ground, it becomes the centre of curvature to a certain portion of the weight of his body, which portion moves in a segment of a circle, over the part which is the temporary axis, the leg being the radius. The surface of the ground, therefore, merely sustains a perpendicular pressure by the animal's hoof, and a proportion of angular pressure when he draws a load, but this latter pressure is, by admirable pliancy of muscle, gradually brought upon the ground so as to prevent any sudden concussion and consequent injury to the road.

Now the case is very different with the propellers in a

steam carriage. Here a solid body is forcing forward a heavy vehicle, by a considerable power pushing upon the road, admitting that the propellers would act in a horizontal direction, or could accommodate themselves to the undulation of the road, still the angular pressure must be excessive, and in cases of increased resistance must of necessity either break the propeller, tear up the road, or overturn the carriage; but where the propeller revolves upon a centre, as in Mr. Gurney's machine, it must of necessity either lift the carriage off its wheels, or make a hole in the road, when acting in its vertical position.

These are some of the difficulties which are to be surmounted, before steam carriages can be brought into useful operation; even then a question arises as to their superiority over the present mode of travelling, either in point of convenience or expense. It appears, by the report of the Darlington and Stockton Railway Company, that the saving effected by the use of loco-motive engines, in place of horses, on that Railway, is about a third. This, be it remembered, is on a railway constructed for the conveyance of coals, and consequently where fuel is almost valueless.

This fact is startling; because, if the saving be so trifling where the cost of coal is not a twentieth part of what it is in some parts of the kingdom—where is the advantage which steam carriages possess?—not, at any rate, in the saving of expense.

But, whatever may be our opinion of what has hitherto been done towards the success of this noble project, we have no right to form any conclusion, as to what may be hereafter effected. It is well known that greater difficulties than any of these have been overcome, by talent and perseverance; and there is no reason to doubt, but that other Newcomens, and Smeatons, and Watts will arise, to vanquish those which remain.

APPENDIX.

SECTION I.

THE NATURE AND PROPERTIES OF STEAM AND OTHER VAPOURS, WHOSE ELASTIC FORCES HAVE BEEN PROPOSED OR EMPLOYED AS MECHANICAL AGENTS FOR PROPELLING MACHINERY, INCLUDING A DISSERTATION ON THE EFFECTS OF HEAT.*

PREVIOUSLY to treating of the effects of steam, it will be necessary to notice the circumstances connected with its production; and this will naturally lead to an investigation of the effects of heat, in causing the bodies to assume the solid, liquid, or aeriform states, according to the quantity of heat in combination with them; without, however, entering upon the subtle question, whether heat be material, as it is supposed to be by Pictet, Murray and others, or whether the cause of heat, or the effects ascribed to heat, arise from the motion amongst the particles of bodies, as is supposed to be the case by the no less eminent philosophers, Bacon, Newton, Boyle, Rumford, Davy, Young, &c. but merely to investigate its various effects on bodies. In this inquiry, it is immaterial which of the theories is adopted, as most of the phenomena connected with the subject may be explained by either.

One of the most obvious properties of heat is to increase, when combined with other bodies, their magnitude, as the following simple experiment will shew.

* The writer of this article has to acknowledge valuable information obtained from the works of Arnott, Biot, Black, Robinson, Watt, and particularly from the Philosophical Transactions.

Fill with mercury a hollow glass globe, to which is attached a very fine tube. The mercury in the globe will be increased in size, or expanded by the application of heat, and will occupy, in addition to the hollow ball, a portion of the tube. And thus, from the difference of the capacities of the ball and tube, a very slight increase in the size of the mercury is rendered apparent.

An instrument, precisely of this form, called a thermometer, has been ingeniously applied to ascertain and enable us to record a great variety of phenomena connected with heat. The thermometer bulb, or hollow ball, being filled with mercury, as above described, heat is applied till the mercury fills the tube as well as the ball. The air being thus expelled, the tube is hermetically closed at the top, and then attached to a scale, so divided, that when the instrument is plunged into freezing water, the surface of the mercury stands at 32°, hence called the freezing point; and when it is plunged into boiling water, the mercury rises to 212°, called the boiling point. The space between these points is divided into 180 degrees, and the divisions are carried above the one and below the other, in such a manner as to indicate, by the altitude of the mercury, the changes in the temperature of the body to which the thermometer is applied. The fixing of the boiling point of water at 212° is perfectly arbitrary, and it is marked differently on different scales; but as the above, introduced by Fahrenheit, are the most common in this country, they will be invariably adopted in this article.

The freezing point on the scale of Reaumur's thermometer is marked 0, and the boiling point 80°; so that the proportion of the divisions on Fahrenheit's scale to those on Reaumur's, is as 180° is to 80°, or as 9 is to 4. There is another scale of divisions, introduced by Celsius, and called the Centigrade Scale, on which the freezing point is marked 0, and the boiling point 100°. So that the proportions of the divisions on this scale, to those on Fahrenheit's, are as 100° to 180°, or as 5 to 9. From these data, the degree of temperature indicated by one thermometer can be easily converted into that which would have been

indicated by another; but as the thermometers, both of Reaumur and Celsius, are much in use on the Continent, it becomes important to have ready means of comparison, and for that purpose the following Table has been introduced.

TABLE I.

Showing the corresponding Degrees on the Thermometers of Fahrenheit, Reaumur, and Celsius.

Fahr.	Reaum.	Centi.	Fahr.	Reaum.	Centi.	Fahr.	Reaum.	Centi.	Fahr.	Reaum.	Centi.
212	80	100	165	59.1	73.8	118	38.2	47.7	71	17.3	21.6
211	79.5	99.4	164	58.6	73.3	117	37.7	47.2	70	16.8	21.1
210	79.1	98.9	163	58.2	72.7	116	37.3	46.6	69	16.4	20.5
209	78.6	98.3	162	57.7	72.2	115	36.8	46.1	68	16	20
208	78.2	97.8	161	57.3	71.6	114	36.4	45.5	67	15.5	19.4
207	77.7	97.2	160	56.8	71.1	113	36	45	66	15.1	18.8
206	77.3	96.7	159	56.4	70.5	112	35.5	44 4	65	14.6	18.3
205	76.8	96.1	158	56	70	111	35.1	43.8	64	14.2	17.7
204	76.4	95.5	157	55.5	69.4	110	34.6	43.3	63	13.7	17.2
203	76	95	156	55.1	68.8	109	34.2	42.7	62	13.3	16.6
202	75.5	94.4	155	54.6	68.3	108	33.7	42.2	61	12.8	16.1
201	75.1	93.8	154	54.2	67.7	107	33.3	41.6	60	12.4	15.5
200	74.6	93.3	153	53.7	67.2	106	32.8	41.1	59	12	15
199	74.2	92.7	152	53.3	66.6	105	32.4	40.5	58	11.5	14.4
198	73.7	92.2	151	52.8	66.1	104	32	40	57	11.1	13.8
197	73.3	91.6	150	52.4	65.5	103	31.5	39.4	56	10.6	13.3
196	72.8	91.1	149	52	65	102	31.1	38.8	55	10.2	12.7
195	72.4	90.5	148	51.5	64.4	101	30.6	38.3	54	9.7	12.2
194	72	90	147	51.1	63.8	100	30.2	37.7	53	9.3	11.6
193	71.5	89.4	146	50 6	63.3	99	29.7	37.2	52	8.8	11.1
192	71.1	88.8	145	50.2	62.7	98	29.3	36.6	51	8.4	10.5
191	70.7	88.3	144	49.7	62.2	97	28.8	36.1	50	8	10
190	70.2	87.7	143	49.3	61.6	96	28.4	35.5	49	7.5	9.4
189	69.7	87.2	142	48.8	61.1	95	28	35	48	7.1	8.8
188	69.3	86.6	141	48.4	60.5	94	27.5	34.4	47	6.6	8.3
187	68.8	86.1	140	48	60	93	27.1	33.8	46	6.2	7.7
186	68.4	85.5	139	47.5	59.4	92	26.6	33.3	45	5.7	7.2
185	68	85	138	47.1	58.8	91	26.2	32.7	44	5.3	6.6
184	67.5	84.4	137	46.6	58.3	90	25.7	32.2	43	4.8	6.1
183	67.1	83.8	136	46.2	57.7	89	25.3	31.6	42	4.4	5.5
182	66.6	83.3	135	45.7	57.2	88	24.8	31.1	41	4	5
181	66.2	82.7	134	45.3	56.6	87	24.4	30.5	40	3.5	4.4
180	65.7	82.2	133	44.8	56.1	86	24	30	39	3.1	3.8
179	65.3	81.6	132	44.4	55.5	85	23.5	29.4	38	2.6	3.3
178	64.8	81.1	131	44	55	84	23.1	28.8	37	2.2	2.7
177	64.4	80.5	130	43.5	54.4	83	22.6	28.3	36	1.7	2.2
176	64	80	129	43.1	53.8	82	22.2	27.7	35	1.3	1.6
175	63.5	79.4	128	42.6	53.3	81	21.7	27.2	34	0.8	1 1
174	63.1	78.8	127	42.2	52.7	80	21.3	26.6	33	0.4	0.5
173	62.6	78.3	126	41.7	52.2	79	20.8	26.1	32	0	0
172	62.2	77.7	125	41.3	51.6	78	20.4	25.5	31	—0.4	—0.5
171	61.7	77.2	124	40.8	51.1	77	20	25	30	—0.8	—1.1
170	61.3	76.6	123	40.4	50.5	76	19.5	24.4	29	—1.3	—1.6
169	60.8	76.1	122	40	50	75	19.1	23.8	28	—1.7	—2.2
168	60.4	75.5	121	39.5	49.4	74	18.6	23.3	27	—2.2	—2.7
167	60	75	120	39.1	48.8	73	18.2	22 7	26	—2.6	—3.3
166	59.5	74.4	119	38.6	48.3	72	17.7	22.2	25	—3.1	—3.8

Fahr.	Reaum.	Centi.	Fahr.	Reaum.	Centi.	Fahr.	Reaum.	Centi.	Fahr.	Reaum.	Centi.
24	—3.5	—4.4	7	—11.1	—13 8	—9	—18.2	—22.7	—25	—25.3	—31.6
23	—4	—5	6	—11.5	—14.4	—10	—18.6	—23.3	—26	—25.7	—32.2
22	—4.4	—5.5	5	—12	—15	—11	—19.1	—23.8	—27	—26.2	—32.7
21	—4.8	—6.1	4	—12.4	—15.5	—12	—19.5	—24.4	—28	—26.6	—33.3
20	—5.3	—6.6	3	—12.8	—16.1	—13	—20	—25	—29	—27.1	—33.8
19	—5.7	—7.2	2	—13.3	—16.6	—14	—20.4	—25.5	—30	—27.5	—34.4
18	—6.2	—7.7	1	—13.7	—17.2	—15	—20.8	—26.1	—31	—28	—35
17	—6.6	—8.3	0	—14.2	—17.7	—16	—21.3	—26.6	—32	—28.4	—35.5
16	—7.1	—8.8	—1	—14.6	—18.3	—17	—21.7	—27.2	—33	—28.8	—36.1
15	—7.5	—9.4	—2	—15.1	—18.8	—18	—22.2	—27.7	—34	—29.3	—36.6
14	—8	—10	—3	—15.5	—19.4	—19	—22.6	—28.3	—35	—29.7	—37.2
13	—8.4	—10 5	—4	—16	—20	—20	—23.1	—28.8	—36	—30.2	—37.7
12	—8.8	—11.1	—5	—16.4	—20.5	—21	—23.5	—29.4	—37	—30.6	—38.3
11	—9.3	—11.6	—6	—16.8	—21.1	—22	—24	—30	—38	—31.1	—38.8
10	—9.7	—12.2	—7	—17.3	—21.6	—23	—24.4	—30.5	—39	—31.5	—39.4
9	—10.2	—12.7	—8	—17.7	—22.2	—24	—24.8	—31.1	—40	—32	—40
8	—10.6	—13.3									

The real quantity of expansion in bodies always exceeds that indicated by the thermometer, inasmuch as the glass vessel which contains the mercury is subjected to an expansion, which prevents the mercury from rising so high in the tube as it otherwise would do.

Though all substances are expanded or dilated by an increase of temperature, yet the expansion produced by the same increase, varies considerably in different bodies. From what has been said, it will be perceived, that to determine, accurately, the expansibility of any fluid by a certain increase of temperature, an allowance must be made for the dilatation of the vessel containing the fluid, and hence the necessity of first determining the expansibility of solid substances; a subject which has been investigated with great care, by Smeaton, De Luc, Dulong, Petit, Lavoisier, La Place, Troughton, Berthoud, Woollaston, and others; and the results of their experiments are given in the following Table, in which the mean expansibilities are inserted, in all cases where the authorities differ.

TABLE II.

LINEAR EXPANSION OF SOLIDS BY HEAT.

Dimensions which a bar takes at 212°, whose length at 32° is 1.00000000.

Glass tube	1.00083357
Plate glass	1.00089089
Ditto crown glass	1.00089694
Glass rod	1.00080787
Deal	1.00080787
Platina	1.00091085
Palladium	1.00100000
Antimony	1.00108300
Cast iron prism	1.00110940
Cast iron	1.00111111
Steel	1.00118990
Ditto rod	1.00114470
Blistered steel	1.00118750
Steel not tempered	1.00107915
Steel tempered yellow	1.00137750
Ditto at a higher rate	1.00123956
Hard steel	1.00122500
Annealed steel	1.00122000
Tempered steel	1.00137000
Iron	1.00120700
Soft iron, forged	1.00122045
Round iron, wire drawn	1.00123504
Iron wire	1.00144010
Bismuth	1 00139200
Annealed gold	1.00146000
Gold	1.00150000
Ditto procured by parting	1.00146606
Ditto, Paris standard, unannealed	1.00155155
Ditto, ditto, annealed	1.00151361
Copper	1.00179413
Brass	1.00184647
Cast brass	1.00187500
English plate brass	1.00189385
Brass	1.00203940
Brass wire	1.00193000
Copper 8, tin 1	1.00181700
Silver	1.00200183
Brass 16, tin 1	1.00190800
Speculum metal	1.00193300
Spelter solder—brass 2, zinc 1	1.00205800
Malacca tin	1.00193765
Tin from Falmouth	1.00217298
Fine pewter	1.00228300
Grain tin	1.00248300
Tin	1.00284000
Soft solder—lead 2, tin 1	1.00250800
Zinc 8, tin 1, a little hammered	1 00269200
Lead	1.00285768
Zinc	1.00297650

The expansibility of fluids being considerably greater than that of solids, it becomes an easy process to ascertain, with a tolerable degree of accuracy, their relative capabilities of expansion, from slight increments of temperature, by inclosing them successively in the same vessel or tube. Glass is found to be very suitable for this purpose, on account of its possessing but small expansive powers, and at the same time great transparency. To determine with great accuracy, however, the comparative expansibilities of different fluids submitted to a considerable change of temperature, much nicety and judgment are required in making the requisite correction for the increased capacity of the containing vessels. MM. Dulong and Petit have devoted much attention to this subject, which they have investigated with their usual precision, and published the results in a Table, which is subjoined.

TABLE III.

Expansion of the Volume of Liquids by being heated from 32° to 212°.

Mercury	0.0177631
Water, its maximum density	0.04332
Muriatic acid (sp. gr. 1.137)	0.0600
Nitric acid (sp. gr. 1.40)	0.1100
Sulphuric acid (sp. gr. 1.85)	0.0600
Alcohol	0.1100
Water	0.0460
Water, saturated with salt	0.0500
Sulphuric ether	0.0700
Fixed oils	0.0800
Oil of turpentine	0.0700

It has been stated that all bodies are augmented by heat; but water, under certain circumstances, forms a remarkable exception to the general law, that all bodies contract in bulk by reduction of temperature. At a temperature of about 40°, water is at its maximum density. If it be reduced to 32°, it expands in the proportion of 9 to 8, and assumes the solid form of ice. An increase of temperature above 40°, has the same effect of expanding water as a decrease from that point. Although water freezes at 32°, yet, if it be kept in a dark and still situation, it may be cooled to 22°, without freezing; but if it be then

gently agitated with a thermometer, it will immediately congeal, and the mercury will rise considerably, when the water assumes the solid form of ice.

This subject may be better understood by reference to the experiments on the quantity of caloric absorbed by ice during its liquefaction.

Aeriform bodies are, when separated from their liquids, uniformly affected, or very nearly so, by equal increments of temperature. Atmospheric air, for example, by an increase of temperature, from 32° to 212° (180°), is expanded from 1 to 1.375; hence the expansibility caused by an increase of one degree is $\frac{.375}{180}$=.002083. A given change of any number of degrees in temperature, therefore, being multiplied by .002083, would show the consequent increase of bulk in the gaseous body. The results of Mr. Dalton's experiments on this subject are given in

TABLE IV.

SHEWING THE EXPANSION OF AIR BY HEAT.

32°	1000	49°	1040	65°	1077	81°	1112	97°	1146
33	1002	50	1043	66	1080	82	1114	98	1148
34	1004	51	1045	67	1082	83	1116	99	1150
35	1007	52	1047	68	1084	84	1118	100	1152
36	1009	53	1050	69	1087	85	1121	110	1173
37	1012	54	1053	70	1089	86	1123	120	1194
38	1015	55	1055	71	1091	87	1125	130	1215
39	1018	56	1057	72	1093	88	1128	140	1235
40	1021	57	1059	73	1095	89	1130	150	1255
41	1023	58	1062	74	1097	90	1132	160	1275
42	1025	59	1064	75	1099	91	1134	170	1295
43	1027	60	1066	76	1101	92	1136	180	1315
44	1030	61	1069	77	1104	93	1138	190	1334
45	1032	62	1071	78	1106	94	1140	200	1354
46	1034	63	1073	79	1108	95	1142	210	1372
47	1036	64	1075	80	1110	96	1144	212	1376
48	1038								

Different bodies removed from one temperature to another, require different quantities of heat to be supplied to or abstracted from each, in order to preserve their equilibrium of temperature. This quality of bodies has been denominated *specific heat*, and it is exhibited in Tables V. and VI.

TABLE V.

SPECIFIC HEATS OF SOLIDS.

	Specific heats, that of water being 1000.	Weight of the atoms, oxygen being 1.	Product of these two numbers.
Bismuth	0.0288	13.300	0.3830
Lead	0.0293	12.950	0.3794
Gold	0.0298	12.430	0.3704
Platinum	0.0314	11.160	0.3740
Tin	0.0514	7.350	0.3779
Silver	0.0557	6.750	0.3759
Zinc..............	0.0927	4.030	0.3736
Tellurium	0.0912	4.030	0.3675
Copper	0.0949	3.957	0.3755
Nickel............	0.1035	3.690	0.3819
Iron	0.1100	3.392	0.3731
Cobalt............	0.1498	2.460	0.3685
Sulphur	0.1880	2.011	0.3780

TABLE VI.

THE SPECIFIC HEATS OF GASES.

Water	1.0000
Air...	0.2669
Hydrogen gas	3.2936
Carbonic acid	0.2210
Oxygen...	0.2361
Azote	0.2754
Oxide of azote..	0.2369
Olefiant gas..	0.4207
Carbonic oxide	0.2884
Aqueous vapour	0.8470

As different bodies contain, at the same temperature, different quantities of heat, the term *capacity for heat* has been also applied, to distinguish this property, and the following table exhibits the comparative capacity of a few of the metals.

CAPACITIES FOR HEAT.

Mean capacity between 0° and 100°.		Mean capacity between 0° and 300°.
Mercury	0.0330	0.0350
Zinc..........	0.0927	0.1015
Antimony	0.0507	0.0549
Silver	0.0557	0.0611
Copper	0.0949	0.1013
Platinum......	0.0355	0.0355
Glass	1.1770	0.1900

It is owing to the quantity of heat in combination with different substances, that they assume the solid, liquid, or aeriform states; thus water, below 32°, becomes solid, and exists only in the state of ice, and above 112°, it becomes steam, and exists only in the state of vapour. As mercury becomes fluid at 48° below zero, we are acquainted with it only as a fluid, and apt to consider that as being its natural state; but this is an accidental condition, entirely depending upon the circumstance of the temperature at which it becomes fluid being below the ordinary temperature of the atmosphere; for fluidity is no more the natural state of mercury, than solidity or vapour is the natural state of water. A considerable quantity of heat combines with all substances during their changes of form, from solid to liquid, or from liquid to vapour. And this heat, which enters into combination with the substances during their changes, not remaining sensible to the thermometer, has received the name of *latent heat*, which is given out again, and becomes sensible to the thermometer, on the contrary change. In the conversion of water into steam, about 1000° disappear, which is six times as much as is required to raise the cold water to the boiling point; a circumstance which is experimentally determined by estimating the time and fuel expended in boiling off a certain quantity of water; and rendered evident by the fact, that any quantity of water in the form of steam, will instantly combine with and raise to the boiling point six times the quantity of cold water. And, on the contrary, a portion of steam will be immediately converted into water, on the abstraction of a portion of its combined heat.

Were it not for the existence of latent heat, and the consequent time required to effect a change in bodies, the process of evaporating by boiling would be impossible; any water or any other liquid would, when raised to a certain temperature, instantly flash into steam, and become dissipated with a terrible explosion, like that of fired gunpowder. For the same reason, the thawing of a large quantity of snow would, without latent heat, be-

come a sudden and disastrous inundation. On the other hand, if water had not to give out its latent heat in freezing, after a quantity of it was once cooled down to the freezing point, the abstraction of one additional degree of heat would be sufficient to convert the whole into a solid mass. Were not the operations effecting the great changes in Nature thus rendered slow and gradual, we should have a succession of the most disastrous explosions and inundations; or seas, lakes, and rivers converted instantly into solid ice. It is somewhat remarkable, that the existence of latent heat, obvious as it thus appears, was unknown till of late years, when its discovery led to such improvements in the steam engine as have affected, in an eminent degree, the relations of great empires. To Dr. Black of Edinburgh, and Mr. James Watt of Glasgow, we are principally indebted for having investigated and made known this discovery. They found that it was not sufficient for converting ice into water, that it should be merely raised to that temperature in which it can no longer remain in the form of ice. A piece of ice, of the of temperature of 32°, will remain a very long time in air the temperature of 50°, before it is entirely melted, continuing all the while of the same temperature 32°, though continually absorbing heat from the surrounding air. By comparing the time in which ice had its temperature changed from 28° to 32°, with the subsequent time of its complete liquefaction, it was discovered that it absorbed about 140 times as much heat as would raise its temperature one degree; and that one pound of ice at 32°, when mixed with one pound of water 140° warmer, was only melted, without increasing the temperature above 32°. Hence it was concluded, that water differed from ice of the same temperature, by containing, as a constituent ingredient, a great quantity of heat, united with it in such a way as to be incapable of quitting it for another colder body, and therefore so as not to act upon the thermometer. Hence the term latent heat. If any more heat were added, after the conversion of the ice into water, it was not latent, but would readily quit it for the thermometer,

and, by causing it to rise, would show what was the degree of this additional heat. In like manner, to convert water into an elastic vapour, it is necessary, not only to increase its uncombined heat till its temperature is 212°, in which state it is just ready to become elastic, but also to add to it a great quantity of heat, which combines with every particle of it, so as to make it repel or recede from its adjoining particles, and thus become a particle of elastic fluid.

In the phenomenon of boiling off a quantity of water, the application of heat to it causes it gradually to rise in its temperature, till it reaches that of 212°. It then begins to send off elastic vapour, and is slowly expended in this way, continuing all the while of the same temperature. The steam also is of no higher temperature, as appears by holding a thermometer in it. We must conclude that this steam contains all the heat which is expended in its formation. Accordingly, the scalding power of steam is well known; but it is extremely difficult to obtain precise measures of the quantity of heat absorbed by water during its conversion into steam. Dr. Black endeavoured to ascertain this point, by comparing the time of raising its temperature a certain number of degrees, with the time of boiling it entirely away, by the same external heat; and he found that the latent heat in steam, which balanced the pressure of the atmosphère, was not less than 800°. He also directed Dr. Irvine of Glasgow, to the form of an experiment for measuring the heat actually extricated from such steam during its condensation in the refrigeratory of a still, which was found to be not less than 774°. Mr. Watt, about the same time, made a course of experiments, with great precision. In 1781, he determined the latent heat of steam, under the ordinary pressure of the atmosphere, to be about 948° or 950°.

Mr. Watt investigated this subject experimentally, which he describes as follows:—He took a pipe of copper $\frac{5}{8}$ths of an inch diameter inside, $\frac{1}{16}$th of an inch thick, and five feet long, having three inches of one of its ends bent

downwards, and fixed it steam-tight on the spout of a tea-kettle, from which the pipe inclined upwards, so that the bent end was about two feet higher than the spout of the kettle; and a cork, perforated with a hole of about $\frac{3}{10}$ths of an inch diameter, kept open by a bit of quill, was fixed in the opening of the bent end.

The tea-kettle was filled with water till it stood half way up the spout; the lid was fixed on tight with some oatmeal dough, and held down by a piece of wood reaching up to the handle. A tin pan, four inches deep and six inches diameter, had 2½ pounds avoirdupois of water put into it, which filled it nearly to 2½ inches deep. The water was weighed very accurately; the tin pan, and a disk of strong paper (oiled with linseed oil, and dried in a stove,) fitted to its inside, being first counterpoised when they were quite dry.

The pan and water were placed upon several folds of flannel on a stand, and the extremity of the cork in the bent end of the pipe was immersed in the water. The water in the kettle was made to boil for some time before the end of the pipe was immersed in the cold water in the pan, which was not done until it was observed that no water dropped from it, but that all the condensed part of the steam returned by the inclined tube to the tea-kettle.

When the end of the tube was immersed in the cold water in the pan, the steam issuing from it was condensed with a crackling noise, and began to heat the water in contact with it. The water being constantly stirred with a circular motion, the heat was thereby diffused equably throughout the whole, and the experiment was continued until the water had acquired the heat of from 70° to 90°, which happened generally in from four to six minutes. Immediately after the thermometer had shewn what the heat was, which was in less than half a minute, the water was covered by the disk of oiled paper, to prevent evaporation, which would otherwise have lessened its weight during the operation of weighing. The thermometer employed became stationary in about 10 seconds.

When the experiments were finished, the tin pan, made quite dry, was set in a room where the air was about 40°, and stood there for half an hour; when it was thought to have acquired the heat of the place, two pounds of water at 76° were then poured into it, and the heat was found to be 75½°.

Then, for 35½° with two pounds of water, or for every 44° with 2½ pounds of water, half a degree must be allowed for the heat absorbed by the pan.

The heat of the room, when the experiments were made, was generally about 56°.

Eleven experiments were made in the foregoing manner, from which the latent heat was calculated according to the following example.

Experiment 1.

The heat of the water in the pan, on beginning the experiment, was 43.5°. When the experiment was ended, the heat of that water was 89.5°, consequently it had gained 46° from the steam it had condensed. The weight of the water on commencing the experiment was 2½ pounds avoirdupois, or 17,500 grains; after the experiment, its weight was 18,260 grains; consequently, it had gained 760 grains from the condensed steam. Thus, multiplying 17,500 grains by 46°, the heat received from the condensed steam, and 0.5°, the heat absorbed by the pan=46.5°, we have 813,750°, which, divided by 760 grains, the weight of the water which in the state of steam communicated the heat, we have 1070°; to this must be added the heat retained, being that of the mixture, 89.5°, which produces 1159.5°, as the sum of the sensible and latent heat of the steam; and deducting 212°, the sensible heat, we have the latent heat 947.5°.

This result, with those of the other ten experiments, tried and calculated in the same manner, are shewn in the following Table.

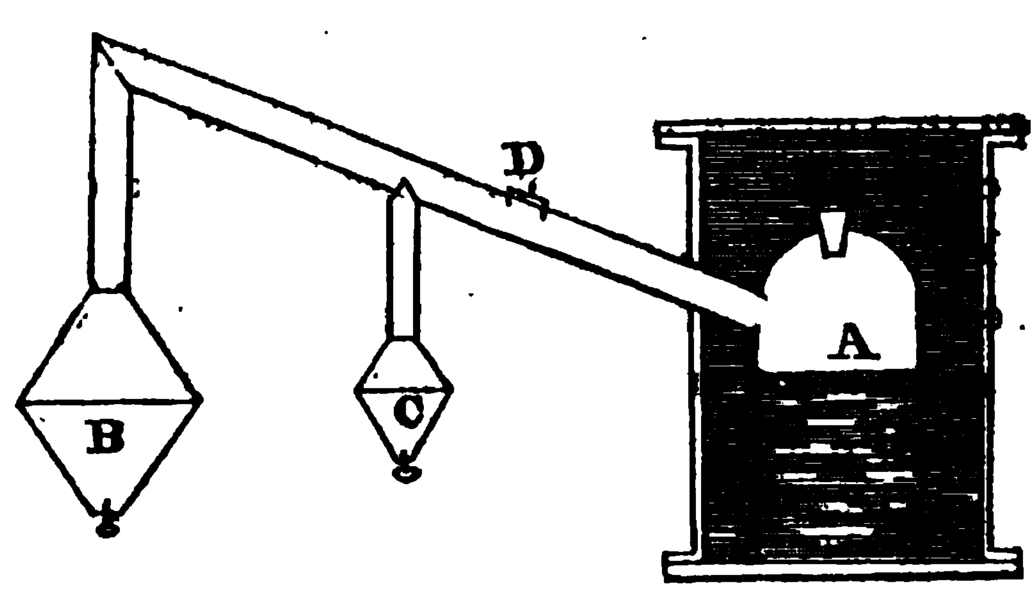
TABLE VII.

No. of Experiments.	Quantity of cold water in the pan.	Temperature of the cold water.	Weight of the condensed steam.	Temperature of the heated water.	Increase of heat.	Total sensible and latent heat.	Latent heat.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.
	Grains.	Deg.	Grains.	Deg.	Deg.	Deg.	Deg.
1.	17,500	43.5	760	89.5	46.5	1159.5	947.5
2.	17,500	44.5	708	86.5	42.5	1136.9	924.9
3.	17,500	44.5	899	98	54	1149.1	937.1
4.	17,500	44.5	467.5	73.5	29.5	1175.6	963.6
5.	17,500	44.5	369	67.25	23	1158	946
6.	17,500	47.5	642	87	40	1177.3	965.3
7.	17,500	49	588.5	84.5	36	1155	943
8.	17,500	47	675	87.5	41	1150.5	938 5
9.	17,500	45	680.5	86.5	42	1166.5	954.5
10.	17,500	45	664.25	85.5	41	1165.66	953.66
11.	17,500	45	975	102	57.5	1134	922

The average of these experiments gives 945.3°, for the latent heat of steam.

But there being, according to Mr. Watt's account, several causes which affect their results, and which for the most part tend to give the latent heat rather less than what it probably was, he estimated the latent heat of steam at 960°.

Mr. Watt, being dissatisfied with the experiments tried in a hasty manner, upon the latent heat of distillation in vacuo, made other experiments, one of which is here described. He took a small still A, surrounded by a bal-



neum, made of tin plate, in the form annexed, which communicated by a pipe with the two double cones B and C, each of which had a very small opening in its lower apex, shut air-tight by a brass plug. There was also an opening, shut in the same manner, in the tube at D. The conical mouth of the still at A, was shut by a good cork.

A pint of water was poured into the inside vessel, and as much into the outside one. The whole was then set upon a chafing-dish, and made to boil. The steam was allowed to issue at B and C, until it was supposed that all the air was expelled. The aperture C was then shut, and just immersed in a vessel of water, to prevent the air from entering. The steam was allowed to issue some time longer at B, and it was also shut, and immediately immersed to a small depth in water. Cold water was then poured into the balneum, so as to cover the orifice and its cork. A degree of exhaustion was instantly produced in the internal vessel, and in the two double cones communicating with it. The double cone B was then wholly immersed in a tin pan, six inches deep, and 8¼ inches in diameter, filled with cold water to within an inch of its mouth. This water weighed 130 oz. 6 dr. 40 gr. troy weight, or 62,800 grains. Its heat, at the beginning of the experiment, was 52°, (say 51.75°). When it was supposed a sufficient quantity had distilled into the receiver B, the heat of the water in the refrigeratory was 61°, consequently had increased 9°, (say 9½°). The plug at D was withdrawn, and the air admitted. The refrigeratory was removed, and the double cone B being wiped dry, its plug was withdrawn, and the water it contained let out, its heat examined, and then weighed. The heat was 62°, and its weight was 1 oz. 54 grs., or 534 grains, to which 6 gr. were added by estimation, for water adhering to the inside of the cone; in all, 540 grains. The heat of the water in the balneum, at the beginning of the experiment, was 134°, and at the end 158°; consequently, at the latter period, about one-third part of air, or other elastic vapour, remained in the still and receiver. The duration of the experiment was nine minutes. The heat of the

chafing-dish was prevented from affecting the refrigeratory by a screen of bricks. The heat of the air in the room was about 58°. The double cone B weighed 1000 grains, and as it was of 134° of heat at the beginning, and was cooled to 62° by the refrigeratory, it lost 72°. Its specific gravity was probably about seven and a half times that of water, and, consequently, its bulk that of $\frac{1000}{7.5}=134.6$ grains of water, and its capacity for heat being about three-fourths of that of the same bulk of water, it would contain the same quantity of heat as about 101 grains of water; and this heat not being communicated by the condensed steam, contained in the cone at the end of the operation, is to be deducted from the heat acquired by the water in the refrigeratory, or, which is the same thing, 101 grains are to be deducted from its weight.

The result of the experiment may be stated as follows:

	Grains.
The weight of the water in the refrigeratory	62800
Deduct 101 grains, as the equivalent for the bulk of the cone	101
Remainder....	62699
Add the heat absorbed by the refrigeratory, which was of tin plate, and weighed 24½ ounces; but for the wire round its mouth, and other parts not in contact with the water, Mr. Watt allowed 4½ ounces, leaving 20 ounces=in bulk to about 1320 grains of water; but its capacity for heat being only two-thirds of that of water, is equal only to 980 grains of water, which is to be added to the water in the refrigeratory	980
Total weight of the water, &c. heated	63679
Which multiplied by 9.25° the heat acquired	589030°.75
And divided by the weight of the condensed steam=540 grains, gives	1090°.79
To which, adding the heat retained	62°
Gives the sum of the sensible and latent heat	1152°.79
From which, deducting the average sensible heat of the steam	146°
Gives the latent heat at that temperature	1006°.79

The following Table, by Dr. Ure, exhibits the latent heat of vapours.

TABLE VIII.

		Corrected Col.
Vapour of water, at its boiling point	967°	1000°
Alcohol, sp. gr. 825	442	457
Ether, boiling point 112°	302.4	312.9
Petroleum	177.8	183.8
Oil of turpentine	177.8	183.8
Nitric acid, sp. gr. 1.494, boiling point 165°	532	550
Liquid ammonia, sp. gr. 0.978	837.3	865.9
Vinegar, sp. gr. 1.007	875.0	903

Substances in the state of gas may, by simple pressure and the abstraction of their combined heat, be reduced to the liquid, or even to the solid form. Mr. Faraday has succeeded in condensing the carbonic acid, chlorine, ammoniacal, and several other gases, into perfect liquids, by great mechanical compression and artificial refrigeration; and several of those substances, which exist in the liquid state under the ordinary pressure of the atmosphere, would assume the gaseous form, if that pressure were removed.

On investigating this subject by experiment, it is found that ether, alcohol, volatile oils, &c. are only known as liquids, from their particles being kept together by the pressure of the atmosphere. Any of these substances, or even water, relieved from such pressure, would expand into a vapour.

The dependance of the three forms which any body may assume, of solid, liquid, or gaseous, on the quantity of heat diffused among its particles, has been already noticed. The effect of accidental pressure, however, must also be considered, as its influence is very important; for, while heat is the power which separates the atoms in the changes mentioned, it has to overcome both the mutual attraction of these atoms, and the force of the atmosphere pressing them together, if in an open vessel; and a much greater pressure even than that, if the substance to be separated be confined in a close vessel, as a high-pressure boiler. The combined influence of mutual attraction and atmospheric or mechanical pressure, is illustrated by the

progress of the change of a liquid into an aeriform fluid, in the process of boiling and evaporation.

If water, in a suitable vessel, be placed over a common fire, or over the flame of a lamp, and heat be gradually communicated to it, small bubbles of aeriform matter (which in water is called steam) are seen forming at the bottom of the vessel, and successively rising to the surface, where they disappear by mixing with the atmosphere; and the operation being continued, the quantity of water diminishes with every bubble, till it entirely disappears in the form of vapour.

This change takes place in water, under common circumstances, at the degree of heat marked 212°; in other substances, it takes place at other fixed temperatures. The relation of water to heat, therefore, is such, that at 212° the repulsive power is just sufficient to overcome both the natural attraction of its particles and the compressing force of the atmosphere, equal to about fifteen pounds on every square inch. If, however, the pressure of the atmosphere be diminished or removed, a less degree of heat is sufficient to make the water boil; and, if pressure be increased, greater heat is required. This becomes evident, when it is considered that water boils on the top of Mont Blanc, at a temperature 32° lower than at the bottom, being free from the pressure of the air below the level of that mountain's summit; and at all intermediate heights, in descending to the level of the sea, there is a corresponding increase of the boiling temperature. Indeed, so exactly is this the case, that the heights of places are ascertained merely by observing the temperature at which water boils on them. While water, under common atmospheric pressure, or when the barometer stands at thirty inches, boils at 212°, other substances, with other relations to heat, have their boiling points higher or lower, as will be seen by the following Table.

TABLE IX.

SOLIDS AND LIQUIDS VOLATILISED.

	Degrees.
Ether boils	98
Liquid ammonia boils	140
Camphor sublimes	145
Sulphur evaporates	170
Alcohol boils	175
Water and essential oils boil	212
Phosphorus distils	219
Solution of muriate of lime boils	230
Nitrous acid boils	242
Nitric acid boils	248
White arsenic sublimes	283
Metallic arsenic sublimes	540
Phosphorus boils	554
Oil of turpentine boils	316
Sulphur boils	570
Sulphuric acid boils	570
Linseed oil boils, and sulphur sublimes	640
Mercury boils	644

The practical engineer will find a convenience in having ready reference to the temperatures at which liquids become solid, or solids liquid, and with that view the following Table has been inserted.

TABLE X.

Freezing Temperatures of Liquids, which are also the Melting Points of Solids.

	Degrees.
Strongest nitric acid	—55
Ether and liquid ammonia	—46
Mercury	—39
Sulphuric acid	—36
Acetous acid	—22
Alcohol 2, water 1	—11
Brandy	—7
Strongest sulphuric acid	1
Oil of turpentine	16
Strong wines	20
Fluoric acid	23
Oils, bergamot and cinnamon	23
Human blood	25
Vinegar	28
Milk	30
Oxymuriatic acid	32
Water	32
Olive oil	36
Sulphuric acid, sp. gr. 1.78	46

	Degrees.
Oil of aniseed	56 to 64
Lard	97
Phosphorus	90
Myrtle wax	109
Spermaceti	112
Tallow	117
Bees' wax	149
Bismuth 5 parts, tin 3, lead 2	212
Sulphur	210
Tin and bismuth, equal parts	283
Camphor	303
Tin 3, lead 2, or tin 2, bismuth 1	334
Tin	427
Tin 1, lead 4	460
Bismuth	476
Lead	582
Zinc	680
Antimony	809
Brass	3809
Copper	4587
Silver	4717
Gold	5237
Cobalt	17977
Nickel	20577
Soft nails	21097
Iron	21637
Manganese	21877
Platinum, tungsten, molybdena, uranium, titanium	23177

It is in consequence of different substances requiring different degrees of heat to produce repulsion enough to raise their particles against the atmospheric resistance, that the distiller is enabled to separate the spirituous from the aqueous particles of any mixture. At 180°, for instance, the spirit will leave the water, and pass off in vapour, which may then be collected and condensed in a fit receiver. Distillation is the best means we possess of separating many substances from each other; as spirit from water, water from acids, water itself from its impurities, and mercury from gold which it has served to dissolve from among the impurities of the mine.

By means of an air-pump, to exhaust the air on one hand, and of the condensing syringe, to condense it on the other, all the facts depending on the atmospheric pressure, and its increase or diminution, may be familiarly illustrated. Thus water, not heated by several degrees to the boiling point of ordinary low situations, but which would boil at the top of high mountains, is made to boil

immediately under the receiver of an air-pump, on the removal of pressure by a few strokes of the piston; and, if the exhaustion be rendered complete, the water will boil even when under blood heat; and at any temperature, however low, water in a vacuum assumes rapidly the form of vapour; but, in such cases, without exhibiting the violent agitation of boiling. Other liquids, as spirits, ether, &c. requiring a less quantity of heat to separate their atoms to repulsive distances, boil under the receiver of an air-pump at very low temperatures. Ether boils when as cold as freezing water.

On the other hand, if the atoms of liquids be confined still more than by a common atmospheric or equivalent pressure, several degrees of heat above the common boiling point will be required to separate them. In a diving bell, immersed in water sixty-eight feet below the surface, the boiling point of water is 272° instead of 212°; and at all other depths, it varies according to the pressure. At the surface of the earth, if water be heated in a close vessel, in which, by condensation, air exerts a pressure of thirty pounds on the inch, instead of fifteen pounds, as in the ordinary atmosphere, or from which the steam is prevented from escaping until it has acquired the force of a double atmosphere, the heat must be raised in a corresponding proportion beyond 212°, before the liquid boils. Under a very strong pressure, water may be rendered almost red hot; but the power with which the atoms are then tending to repel each other, occasions an almost irresistible force of expansion, and as soon as the pressure is removed, a portion of it flashes into steam and escapes, carrying with it a large portion of water, in a highly-divided state.

The determination of the elastic force of steam of different degrees of temperature, is of the greatest importance to the practical engineer, and the subject has consequently undergone much investigation, both by able mathematicians and accurate experimentalists. Mr. Creighton, Mr. Southern, Dr. Young, Mr. Tredgold, and Mr. Ivery, have severally undertaken the inquiry,

with a view to deduce, from the best experiments, a rule by which the force of steam at any temperature, or the temperature corresponding to any given force of steam, could be determined.

The following rule, given by Mr. Tredgold, is more simple than any of the others, and the correspondence between its results and the best experiments, shows it to be sufficiently accurate for all practical purposes.

The temperature in degrees of Fahrenheit's thermometer, increased by 100, divided by 177, and raised to the sixth power, will give the force of the steam in inches of mercury; thus—

Let the given temperature be 307°, then $\left(\frac{307+100}{177}\right)^6 = 2.3^6$, or $2.3 \times 2.3 \times 2.3 \times 2.3 \times 2.3 \times 2.3 = 148.035889$, the force of the steam in inches of mercury, which corresponds, within two tenths of an inch, with the force determined experimentally, and given in the subjoined table. This arithmetical computation may be much shortened by the use of logarithms, for the difference between the logarithm of the given temperature increased by 100, and that of 177, being multiplied by 6, will be the logarithm of the force of the steam, thus—

307+100=407	Log =2.6095944
177	Log.=2.2479733
	·3616211
	6
Force of steam, 147.82	Log. 2.1697266

This is about .2 of an inch less than the other result; a difference which is to be accounted for, from 2.3 being somewhat greater than the quotient of $\frac{407}{177}$.

When the force of the steam is given, to find the temperature, these operations of course must be reversed. The logarithm, for instance, of the force of the steam in inches of mercury, divided by six, and increased by the logarithm of 177, will be the logarithm of the temperature added to 100.

The experiments of Mr. Watt, Mr. Dalton, Dr. Robison, Mr. Southern, Dr. Ure, Mr. Arsherger, and Mr.

Philip Taylor, have all been of great service in determining this question; but those of Mr. Dalton and Mr. Taylor, being the most complete and extensive, are given in the following Table, the first part of which, up to 212°, is the result of Mr. Dalton's experiments, and the latter part is the result of those of Mr. Philip Taylor.

TABLE XI.

Showing the Elastic Force of Steam, from 32 *to* 320 *Degrees of Temperature.*

Temperature.	Force in inches of mercury.	Temperature.	Force in inches of mercury.	Temperature.	Force in inches of mercury.	Temperature.	Force in inches of mercury.
32	0.200	71	0.745	110	2.53	149	7.23
33	0.207	72	0.770	111	2.60	150	7.42
34	0.214	73	0.796	112	2.68	151	7.61
35	0.221	74	0.823	113	2.76	152	7.81
36	0.229	75	0.851	114	2.84	153	8.01
37	0.237	76	0.880	115	2.92	154	8.20
38	0.245	77	0.910	116	3.00	155	8.40
39	0.254	78	0.940	117	3.08	156	8.60
40	0.263	79	0.971	118	3.16	157	8.81
41	0.273	80	1.00	119	3.25	158	9.02
42	0.283	81	1.04	120	3.33	159	9.24
43	0.294	82	1.07	121	3.42	160	9.46
44	0.305	83	1.10	122	3.50	161	9.68
45	0.316	84	1.14	123	3.59	162	9.91
46	0.327	85	1.17	124	3.69	163	10.15
47	0.338	86	1.21	125	3.79	164	10.41
48	0.350	87	1.24	126	3.89	165	10.68
49	0.362	88	1.28	127	4.00	166	10.96
50	0.375	89	1.32	128	4.11	167	11.25
51	0.388	90	1.36	129	4.22	168	11.54
52	0.401	91	1.40	130	4.34	169	11.83
53	0.415	92	1.44	131	4.47	170	12.13
54	0.429	93	1.48	132	4.60	171	12.43
55	0.443	94	1.53	133	4.73	172	12.73
56	0.458	95	1.58	134	4.86	173	13.02
57	0.474	96	1.63	135	5.00	174	13.32
58	0.490	97	1.68	136	5.14	175	13.62
59	0.507	98	1.74	137	5.29	176	13.92
60	0.524	99	1.80	138	5.44	177	14.22
61	0.542	100	1.86	139	5.59	178	14.52
62	0.560	101	1.92	140	5.74	179	14.85
63	0.578	102	1.98	141	5.90	180	15.15
64	0.597	103	2.04	142	6.05	181	15.50
65	0.616	104	2.11	143	6.21	182	15.86
66	0.635	105	2.18	144	6.37	183	16.23
67	0.655	106	2.25	145	6.53	184	16.61
68	0.675	107	2.32	146	6.70	185	17.00
69	0.698	108	2.39	147	6.87	186	17.40
70	0.721	109	2.46	148	7.05	187	17.80

Temperature.	Force in inches of mercury.	Temperature.	Force in inches of mercury.	Temperature.	Force in inches of mercury.	Temperature.	Force in inches of mercury.
188	18.20	222	36.20	255	64.40	288	110.80
189	18.60	223	37.00	256	65.50	289	112.65
190	19.00	224	37.50	257	66.60	290	114.50
191	19.42	225	38.00	258	67.75	291	116.40
192	19.86	226	38.80	259	69.00	292	118.30
193	20.32	227	39.50	260	70.12	293	120.25
194	20.77	228	40.20	261	71.25	294	122.20
195	21.22	229	40.85	262	72.45	295	124.15
196	21.68	230	41.55	263	73.52	296	126.05
197	22.13	231	42.25	264	74.80	297	128.00
198	22.69	232	43.00	265	76.00	298	129.80
199	23.16	233	43.75	266	77.25	299	131.62
200	23.64	234	44.60	267	78.50	300	133.75
201	24.12	235	45.50	268	79.80	301	135.60
202	24.61	236	46.40	269	81.14	302	137.55
203	25.10	237	47.30	270	82.50	303	139.75
204	25.61	238	48.20	271	83.90	304	141.90
205	26.13	239	49.10	272	85.45	305	144.05
206	26.66	240	50.00	273	86.95	306	146.15
207	27.20	241	50.90	274	88.50	307	148.30
208	27.74	242	51.75	275	90.00	308	150.65
209	28.29	243	52.62	276	91.55	309	152.70
210	28.84	244	53.50	277	93.15	310	155.00
211	29.41	245	54.40	278	94.70	311	157.20
212	30.00	246	55.30	279	96.26	312	159.45
213	30.59	247	56.25	280	97.75	313	161.75
214	31.19	248	57.20	281	99.25	314	164.20
215	31.80	249	58.20	282	100.70	315	166.70
216	32.40	250	59.12	283	102.20	316	169.15
217	33.00	251	60.10	284	103.80	317	171.70
218	33.70	252	61.12	285	105.60	318	174.30
219	34.20	253	62.15	286	107.30	319	176.80
220	35.00	254	63.20	287	109.00	320	179.40
221	35.50						

The foregoing rules and table apply only when pure water is used, and as there are numerous instances in which engines are worked by steam from salt water, it becomes necessary for practical men to have the means of readily determining the elastic force of steam from water impregnated with different proportions of salt. The proportion of salt in a boiler supplied with sea water, will continue to increase during the evaporation, until the water becomes saturated, and contains $\frac{12}{33}$ of salt; when the elastic force of the steam at the temperature of 307° will be 113.38, which is less by 34.44 inches of mercury, than the force of steam from pure water, as calculated at page 356.

To facilitate the computations of the force of steam from water of different degrees of saltness, a table, with the boiling temperature, and the constant numbers to be used as divisors instead of 177, is subjoined. The proportion of saltness can, in all cases, be obtained from the specific gravity of the water.

TABLE XII.

Exhibiting the Temperature at which Water containing different proportions of Salt boils, and the Numbers to be used in calculating the force of Steam therefrom.

Proportion of salt.	Boiling points.	Number for calculating.
Common water. . . .	212°	177
Sea water. . . . . $\frac{1}{33}$	213.2	177.6
$\frac{2}{33}$	214.4	178.3
$\frac{3}{33}$	215.5	179
$\frac{4}{33}$	216.7	179.7
$\frac{5}{33}$	217.9	180.4
$\frac{6}{33}$	219	181
$\frac{7}{33}$	220.2	181.6
$\frac{8}{33}$	221.4	182.3
$\frac{9}{33}$	222.5	183
$\frac{10}{33}$	223.7	183.6
$\frac{11}{33}$	224.9	184.3
Saturated solution $\frac{12}{33}$	226	185

On the subject of the conducting powers of different bodies for heat, Colonel Sir B. Thompson and M. Despretz have made many experiments. In examining the conducting power of air, and of various other fluid and solid bodies, with regard to heat, the Colonel was led to investigate the conducting power of a Torricellian vacuum. From the striking analogy between the electric fluid and heat, respecting their conductors and non-conductors, (having found that bodies in general, which are conductors of the electric fluid, are likewise good conductors of heat; and, on the contrary, that electric bodies, or such as are bad conductors of the electric fluid, are likewise bad conductors of heat,) he was led to imagine

that the Torricellian vacuum, which is known to afford so ready a passage to the electric fluid, would also have afforded a ready passage to heat. The common experiments of heating and cooling bodies under the receiver of an air-pump, he concluded inadequate to determine this question, not only on account of the impossibility of making a perfect void of air by means of the pump, but also on account of the moist vapour which, exhaling from the wet leather and the oil used in the machine, expands under the receiver, and fills it with a watery fluid, which, though extremely rare, is yet capable of conducting a great deal of heat; he had recourse, therefore, to other contrivances

It appears that the Torricellian vacuum, which affords so ready a passage to the electric fluid, so far from being a good conductor of heat, is a much worse one than common air, which of itself is reckoned among the worst: for, when the bulb of the thermometer was surrounded with air, and the instrument was plunged into boiling water, the mercury rose from 18° to 27°, in 45 seconds; but in the former experiment, when it was surrounded by a Torricellian vacuum, it required to remain in the boiling water 1 minute, 30 seconds=90 seconds, to acquire that degree of heat. In the vacuum, it required five minutes to rise to $48\frac{4}{10}$, but in air it rose to that height in 2 minutes 40 seconds; and the proportion of the times in the other observations was nearly the same.

It appears from other experiments, that the conducting power of air to that of the Torricellian vacuum, under the circumstances described, is as 1000 to 702, nearly; for the quantity of heat communicated being equal, the intensity of the communication is inversely as the times.

By others, it appears that the conducting power of air is, to that of the Torricellian vacuum, as $9\frac{44}{60}$ to $16\frac{18}{60}$ inversely, or as 1000 to 603.

Taking now the conducting powers of mercury=1000, the conducting powers of the other media, as determined by these experiments, will be as annexed, viz.

Mercury	1000
Moist air	330
Water	342
Common air, density=1	$80\frac{3}{5}$
Rarefied air, density=$\frac{1}{4}$	$80\frac{1}{4}$
Rarefied air, density=$\frac{1}{24}$	78
The Torricellian vacuum	55

And in these proportions is the quantity of heat which these different medias are capable of transmitting in any given time; and, consequently, these numbers express the relative sensible temperatures of the media, as well as their conducting powers.

Comparative Power of various Substances for conducting Heat.

From a series of experiments very carefully conducted, M. Despretz has obtained the following results.

Gold	1000.0
Silver	973.0
Platina	981.0
Copper	898.2
Iron	374.3
Zinc	363.0
Tin	303.9
Lead	179.6
Marble	23.6
Porcelain	12.2
Fire bricks	11.4

All the bars used were square prisms. Cavities were made in them at equal distances of 10 centimetres,* to receive the bulbs of small thermometers. The side of the section, except for the two last bodies in the list, was equal to 21 millimetres.† The bars were covered with the same varnish, to give them an equal radiating power. The bar experimented with, was heated at one extremity with a small stove, which had the advantage of being governed readily, and of causing but little heat in the place. The temperature of the air was ascertained by a sensible thermometer, and it was found easy to make it

* A centimetre is=.39371 of an English inch.

† A millimetre is=.03937 ditto.

nearly uniform for the whole of an experiment. Each experiment continued six hours, and it was only after two or three hours that all the thermometers became stationary. The thermometer nearest to the source of heat acquires the temperature at which it is to be retained stationary, and then the heat is managed so that it shall not rise nor fall by that instrument until the experiment is finished.

Wood conducts so feebly, that a bar of 21 millimetres does not become sensibly heated, a few centimetres from one of its extremities, so far-raised in temperature as to carbonise the substance.

Heat in Flues.

Numerous experiments have lately been made in France, for ascertaining the laws regulating the rapidity with which hot air passes through flues, &c. The results appear to be,—first, that flues oppose to the passage of hot air, a resistance proportioned to the length of the pipe, the square of the rapidities, and in an inverse ratio to the diameter:—secondly, that the co-efficient of friction, is not the same with reference to different substances:—thirdly, that by narrowing the inferior orifice of a flue, the body of air passing through diminishes solely in proportion to the diameter of the orifice, and, consequently, that the rapidity in the orifice itself, increases in an inverse ratio to its diameter. The two last results are capable of numerous applications to the useful arts.

It now appears, that the diameter of the chimney is also a powerful element in draught; limited, when the superior orifice is fixed, indefinite when it is not so; and this element costs very little expense.

SECTION II.

ON STEAM ENGINE BOILERS.

It is a current opinion among engineers, that so much has already been done towards perfecting the steam engine, that there remains very little more to effect in its improvement, and, consequently, that the efforts of the mechanic and the man of science would be more profitably directed towards improving the construction of the boiler, or apparatus for generating the steam.

As steam appears to be simply water in a highly rarefied state, produced by the repulsive power of heat insinuating itself between its particles, it follows that a given quantity of heat can only convert a given quantity of water into steam, no matter under what form of apparatus the heat be applied, provided it be made to enter the water. That boiler is therefore the best for general purposes, in which the least portion of the heat given out by the fuel is wasted; or, (in other words) that by which the greatest quantity of heat is made subservient to the production of steam. But as a draught of air through the grate to the chimney is necessary to combustion, some loss of heat from this cause appears to be unavoidable; and to reduce this loss to its minimum, ought to be one of the principal objects in the construction of a steam boiler. This object is best attained by causing as much as possible of the heated air to impinge *upward* on the under surface of the boiler; as, from the tendency of heat to rise, the *lateral* effect of it is very little, and the *downward* effect still less:—these remarks, however, only apply to boilers of the common forms.

Now, as the heat is to be transmitted *through* the substance of the boiler to the water, it is of essential import-

ance that the material of which the boiler is constructed should be the best conductor of caloric; for this reason, copper is greatly superior to iron, but the latter generally obtains a preference on account of its smaller cost; and possibly, with some persons, on the ground that iron possesses greater tenacity or cohesive strength than copper.

We are, however, disposed to think that true economy would be best attained by the employment of copper boilers, for several reasons. First, as respects the cost price; the labour of working copper and iron being nearly alike, need not be taken into account; the difference of cost, therefore, lies only in the relative value of the two metals, the iron being two-pence per pound and the copper twelve-pence. But when an iron boiler is worn out, the old metal is scarcely worth the expense of removal, while the old metal of a copper boiler is worth ten-pence per pound (two-pence per pound being the price charged at the mills for converting old copper into new); ten-pence per pound being thus returned to the purchaser, the money actually sunk is not more than in the case of the iron.

The experiments of various philosophers have shown that iron possesses greater cohesive strength than copper; the average of their calculations (as they vary considerably,) will make the difference of strength about one-third; but owing to the greater uniformity of the crystalline or fibrous arrangement, and greater freedom from flaws, copper is, to a certain extent, more to be depended upon than iron plates, in the state they are received from the mills. At least, this view of the subject is entertained and acted upon by manufacturers, who uniformly make copper boilers of much *thinner* plates than those of iron, for producing steam of the same pressure. Experience has, we believe, established this as a rule, probably from observing that when a copper boiler bursts, it only *tears open*, while a wrought-iron boiler is often *blown to pieces*, destroying every thing in its way; this circumstance reduces the first cost of the copper.

By a reference to the table of the comparative conducting power of various substances, at page 361, it will be seen that the advantages, in this respect, of copper, are so great as to entitle it to a decided preference; especially for locomotion, in which a reduction of bulk and weight is of the utmost value. An iron boiler, of the *same* thickness as a copper one, will require more fuel to produce the same effect or quantity of steam in a given time; for it is evident that a portion of the heated matters that impinge upon the surface of a copper boiler is not taken up by it, and as the conducting power of iron is less, a greater quantity of the products of the fuel must pass off misapplied, or wasted. Although we are furnished with the ratio of the conducting powers of the two metals, we are still unable to estimate precisely their relative practical advantages; for, if the time which elapses between the heated air impinging against the bottom of the boiler, and its entering the chimney, be greater than the time which the caloric would occupy in passing through an iron boiler, it follows that the effects would not be in the same ratio as the conducting powers of the metals.

The rupturing of vessels exposed to heat is owing not unfrequently to the unequal expansion; and for that reason, the thicker their substance, the greater their liability to fracture. The thin glass oil-flask withstands the heat of an argand lamp, but thick glass vessels infallibly break; this arises from glass being nearly the worst conductor of heat, the heated part expanding, while the cool parts do not, a separation takes place. Cast-iron boilers often burst from the same cause; wrought-iron boilers, being better conductors of heat, are safer than cast-iron; and copper boilers are, for the same reason, preferable to wrought-iron. Our limits prevent us from entering so fully into these points as we could wish, but the advantages of copper boilers over iron are, we think, sufficiently apparent, from the foregoing considerations.

In the construction of boilers generally, the bottom surface should be of sufficient extent to be capable of absorbing as much heat as will be necessary to produce the

required quantity of steam; what little heat may be given out laterally, serving to prevent condensation in the upper part of the vessel (or vessels); and the smoke, before it passes up the chimney, should be robbed as much as possible of its heat, by being brought into contact with the conduit pipe, by which the boiler is supplied with cold water.

There is a considerable waste of fuel in producing steam by intensity of heat upon a small surface; the application of a moderate heat (800° Fahrenheit) upon a large surface, being far more economical. A cubic foot of water converted into steam per hour, has been reckoned as equivalent to one horse's power; and Mr. Watt has observed, that this quantity of steam could be raised per hour by eight feet of surface of boiler, in a judiciously constructed furnace. In practice, it is usual to allow from four to five feet of bottom surface of boiler, to raise one cubic foot of water into steam per hour.

It is considered essential that a boiler should contain four or five times as much water as it boils off per hour; and it is obvious that it should have a space above the water, capable of containing as much steam as will supply the engine at each stroke, without materially diminishing its elastic force; for this purpose, the steam room should hold a volume equal to the supply of eight or ten strokes of the engine.

In large engines, it is usual to employ two, three, or more boilers to supply them with steam; one of them being reserved for use, in case of repairs being required to the others. In fact, a spare boiler should be provided, wherever stoppages are of serious importance in a concern; for this reason, there are two boilers to only a ten-horse engine, at the London Portable Gas Works, each boiler being used alternately.

The strength of high-pressure boilers should be at least three times the regulated pressure on the safety valve; for low-pressure boilers, a strength equal to twice the pressure on the safety valve may be deemed sufficient.

There are many other circumstances, in the construction

of a boiler, that should be taken into consideration; but as the limits of this treatise preclude our enlarging upon this head, we refer the inquisitive reader to Mr. Tredgold's excellent work on the steam engine, where the subject is very ably treated.

Upon the form of boilers much of their strength depends; this circumstance, as well as many others, will be considered in the descriptions of a variety of new contrivances for generating steam, contained in the following pages. In the early part of this work, the globular, the semi-spherical, the cylindrical, the waggon-shaped, and a variety of other forms, have been duly noticed along with the accounts of the steam engines to which they formed appendages. Those that follow, possess fair claims to attention, either as matter of history, or for their intrinsic merit. As it would be a needless task to class them, we have simply arranged them in the order of their dates, concluding the description of them, with a few brief critical remarks on their properties.

(FIG. 2.) (FIG. 1.)

(Patent Steam Engine Boiler, by Horton and Fisher, of Birmingham. 1823.*)*

The peculiarity in this invention seems to consist in the placing of a reservoir for the steam generated, within the boiler; which steam, being constantly surrounded with hot water, loses none of its heat by radiation. These

boilers the applicable to either high or low pressure engines, with such modifications of their form, and in the strength of the materials, as the case may require.

Fig. 1 represents a longitudinal section of the boiler, and fig. 2 a transverse vertical section of the same. The letters of reference apply to the same parts in each of the figures.

a a a, figs. 1 and 2, show the external form of the boiler, round which the furnace and flues are to be constructed; *b b b* is the internal vessel, or reservoir for containing the steam generated; *c c* exhibits that part of the boiler that is filled with water, which is replenished by means of the tube *o o*, from another reservoir placed above. The heat having caused the steam to fill the upper part of the boiler *d d*, it passes from thence through the bent tube *e e*, into the steam reservoir *b b* below, from whence it is conveyed to the engine, through the tube *e*.

At the upper part of the tube *e*, at *n*, a safety valve is placed, for regulating the force of the steam. At *f* is a cock for drawing off whatever water may be formed in the steam reservoir, and under this, at *k*, is an aperture for cleaning out the boiler: *l l* are man holes for gaining access into the interior, whenever necessary.

The boiler is of a novel and ingenious construction, and as it has doubtless been put in practice by the patentees, who are large manufacturers of steam boilers, it may deserve investigation, to determine how far the exposure of that portion of the boiler containing the water to the loss of heat by radiation, is superior to the exposure of the portion containing the steam.

Patent Capillary Steam Boilers, by John Theodore Paul. London, 1824.

The superior strength and safety of tubular boilers have led to a great variety of applications of the principle, both at home and abroad. That which we have now to describe is the invention of a native of Geneva, and we understand that it has been advantageously applied to the

working of an engine; but we are not in possession of any authentic data by which we can come to a conclusion of its practical merits: the arrangement of this patentee is, however, deserving of a brief description, especially as we have noticed patented inventions of a later date, having a close resemblance to this.

Mr. Paul employs a long copper (or other metal) pipe of small diameter, coiled round the inside of the furnace into a conical figure, within which the fuel is situated. The interior of the furnace thus constructed, is enclosed by a casing of sheet iron, with flanges fixed round the interior for supporting the coils of pipe, a portion of which is so bent as to form a kind of grating, on which the fuel is laid. The fuel is supplied through the upper part of the cone where the smoke escapes, or it may be by an aperture made in the side of it, between the coils, for that purpose. The casing may be single or double; the latter is preferable, where the increased weight of the apparatus is not an objection, in which the space between the two cases is filled with brick-dust, ashes, or any other slow conductor of heat. When the single case only is used, it is to be coated by substances of a similar nature, to prevent the radiation of heat.

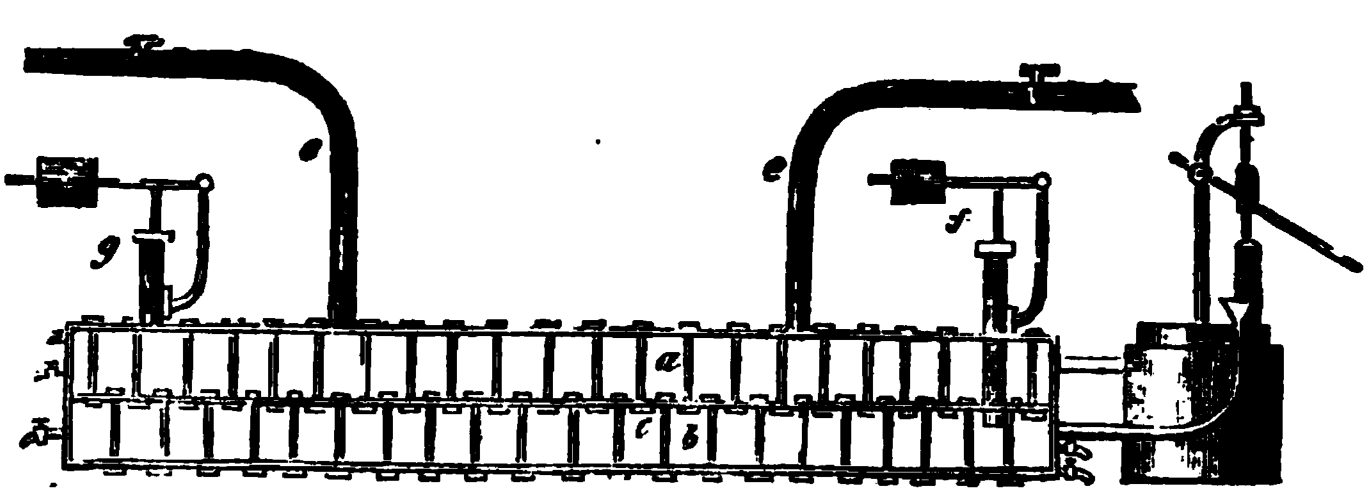
When the fuel is ignited, and the pipes are heated to redness, the water is injected by a force pump, in such small portions as to cause it to be immediately converted into steam, which steam receiving a continual accession of heat in its revolutions round the furnace, escapes ultimately at the other extremity, at a very high temperature, in which state it enters the engine. The boiler we have now described, the patentee designs for general purposes.

For locomotive carriages, Mr. Paul purposes to construct a coiled tubular boiler of a different form. This may be described as the upper and lower frustrum of the same hollow cone; the base of the latter, which is the largest, is placed upwards, and the former is placed within it, with its base or broadest end downwards. As the upper parts of these frustra of the cone now diverge from each other, and their lower edges are in contact, it

is easy to conceive this figure to be formed of one continuous coiling of the same pipe; this furnace is supported by a circular frame work, or enclosed in a case formed of non-conducting materials. The interior cone of pipes rises to about two-thirds of the height of the exterior, and the fuel, which is supplied by an air-tight box, is heaped up between them; the ashes pass through a hollow inverted cone, into a receptacle beneath. Air is supplied to the fuel by means of a pipe passed through the ash-hole, and the force of the current increased by the action of bellows.

In this form of boiler, the water should be injected from the upper extremity, and having descended to the lower, ascend the interior cone, receiving an increased degree of heat, until it escapes at the upper extremity of the latter, in the state of highly-compressed steam. For an engine of two-horse power, the patentee purposes a tube of 150 feet in length, with an internal diameter of only three sixteenths; thickness, one sixteenth; making the external diameter only five sixteenths of an inch. Engines of greater power to have tubes of proportionably greater dimensions.

Mr. Joseph Buchanan, of the United States, invented, constructed, and published, at about the same period of time, a description of a boiler of precisely the same kind as the foregoing. Both the inventions are probably original, and the inventors are also entitled to the credit of having introduced capillary boilers, which will be found a great convenience wherever they raise sufficient steam.



Patent Steam Engine Boiler, by Mr. Smith, of London, 1824.)

This boiler is a modification of a steam apparatus first introduced by the patentee for the evaporation of sugar, salt, &c. The former invention consisted in the application of the lower vessel *b* alone; the engraving represents it in section, and the figure of it is supposed to be a parallelogram. The top and bottom of this vessel are strongly tied together by means of screw bolts, which are placed at about nine inches apart over its whole space, and thus great strength is obtained in a boiler, with the advantages of very thin metal, by which the heat is more readily transmitted. The water was supplied to this vessel by means of a pipe and funnel; it had a guage cock for ascertaining the depth of water, and two drawing off cocks; a safety valve *f* was likewise attached, with a variable weight.

The present invention consists in adding to the part already described the upper vessel *a*, which is constructed in the same manner as the lower one; but so that the upper part of the lower one forms the bottom of the upper one, or, as it were, a partition *c* between them. A pump supplies the boiler with water; at the other end are placed two guage cocks, also a safety valve *g*, loaded with a variable weight, to regulate the pressure.

About two inches deep of water are put into the lower vessel, and the other being half filled, the fire is lighted, which quickly raises the water in the lower vessel to ebullition, the stream of which acts upon the lower surface of the upper boiler, giving out its heat to the water contained therein: but becoming itself thereby condensed, it falls back in a shower into the boiling water below, and being thus alternately vapourised and condensed, sufficient heat is given off to the contents of the upper vessel, to convert that into a steam chamber of a uniform temperature, and of any required degree of pressure. The steam is conveyed from the upper vessel, along the pipes *e e*, to actuate the engine.

As by this apparatus, two shallow strata of water, separated by very thin metallic plates, are exposed to the direct action of heat, the transmission of it, and the con-

version of the water into steam, is very rapid; consequently, a boiler of this kind, might be found desirable for an engine where stoppages are frequent. The expense of one of these vessels must, we think, be greater than an ordinary boiler of equal capacity, on account of the labour attending the making of so many joints steam-tight, and the subsequent difficulty of keeping them so.

Patent method of changing the Water in Steam Engine Boilers, by Messrs. Maudslay and Field, of Westminster Bridge Road, 1824.

On account of the great deposition of salts and earthy matter, chiefly calcareous, on the bottom and sides of the boilers, when sea water is employed for the production of steam, the patentees (who are eminent steam-engine manufacturers) have proposed an arrangement of apparatus, applicable to steam boats, by which the water is continually being changed, and by that means obviates a great practical inconvenience at present existing. In making long voyages, the boilers sometimes become so charged with brine, as to render it *expedient* to stop the progress of the vessel, in order to discharge the contents of the boilers, and fill them anew with sea water; for, if the heat be continued after a considerable deposition has taken place, the steam can only be raised by a greatly increased expenditure of fuel, and the augmentation of the heat seriously injures the tenacity of the metal, of which the boilers are composed.

The patentees state, that from 20 to 30 per cent. of the quantity of water evaporated being taken from the concentrated brine, will keep the water within a degree of saltness, from which no practical evils will result, however long the boiling be continued; the quantity thus abstracted from the boiler being of course replaced by a like quantity of sea water in its natural state.

The abstraction of the brine is made by means of a small pump, with a loaded discharge valve, worked by the engine, and so proportioned as to draw from the lowest part of the boiler the quantity determined on;

which may be regulated by a meter, showing the quantity of water driven off in the form of steam. The operation of the pump is, however, not to commence until the brine has attained a considerable degree of concentration; it should, for instance, contain five times as much salt as common sea water; after this, every stroke may be made, by means of the pump, to take *as much salt out of the boiler, as is deposited in the boiler by the steam used in that stroke.** By these means, the water in the boiler can never exceed a certain predetermined degree of saturation; and whether the engine be working quickly or slowly, the quantity withdrawn may always be made to bear the same proportion to the quantity left in, thus avoiding one of the greatest evils to which steam vessels, in making long voyages, have hitherto been subjected.

To economise the heat and consequent expenditure of fuel, the patentees further purpose that the hot brine extracted by the pump, be discharged into a vessel containing a series of metal pipes of a small calibre, similar to a refrigeratory. Through these pipes, which lie immersed in the hot brine, the supply water is to be made to pass,

* As this may not be readily understood by some readers, we shall here endeavour to explain it, by a numerical statement. The quantity of salt in the water of our seas (the German Ocean, for instance,) is about three per cent., consequently, a vessel holding 1000 pounds of sea water, contains in solution 30 pounds of salt. By evaporation the water is driven off, leaving the brine more concentrated; and constant additions of salt water being made to supply the waste by evaporation, the water in the boiler gradually increases in saltness, until it contains five times as much salt as common sea water. The 1000 pounds of water in the boiler, therefore, now holds 150 pounds of salt in solution, or 15 per cent. Now, supposing that 200 pounds of pure water be driven off by steam in a given time, and in the same period of time, that 50 pounds of the brine be extracted by the pump, the latter holding 7½ pounds of salt in solution, will take that quantity of salt with it out of the boiler. The total loss of the boiler is, therefore, 250 pounds of water, containing 7½ pounds of salt; and this proportion of salt is exactly what is contained in 250 pounds of common sea water, with which the boiler has been replenished during the same period of time.

n order to abstract the heat in its progress, and deliver the sea water into the boiler in a heated state.

This invention confers great credit on the eminent patentees; nor do we see any obstacle to the judicious arrangements herein purposed, being carried into full effect.

(*Patent "Steam Chambers," by John M'Curdy, of Cecil Street, London,* 1824.)

This invention originated in America, where great anticipations were entertained of its utility, and it was announced in the public journals of England and Europe generally, not merely as an important discovery in science, but as forming almost an era in the History of the Steam Engine. Mr. M'Curdy brought the invention over to this country, took out a patent, and subsequently sold his patent right for a large sum of money.

The construction of this apparatus is shewn by the preceding cut, which represents a longitudinal section. A single tube *a*, of considerable thickness, is made of wrought iron, and of the following proportions:—length, 11 feet; diameter, six inches at the large end, and tapering gradually to the other end, where it is only three inches in diameter. It is bent into the form represented in the figure. Into the large extremity of this tube, is inserted an injection barrel, closed at the extremity *b*, but having very numerous minute perforations over the rest of its surface in the tube; the other end of the injection

barrel *c* is connected to a forcing pump. *d* is the pipe which conducts the steam to the engine.

This vessel is placed in a furnace, and when heated sufficiently, the water is forced, by means of the pump, through the injection barrel, by which it is distributed in a finely divided state over the interior surface of the heated chamber, which instantly converts it into steam of very high pressure.

It was stated by the patentee, that a patent steam chamber of the dimensions we have given, is capable of generating as much steam as a boiler containing 150 cubic feet. To increase the power, it was purposed to increase the number of the steam chambers, each of which was to be supplied by a distinct pump. It was further stated, that a cubical inch of water, injected into one of these chambers, and flashed into steam, afforded sufficient for one stroke of a four-horse engine.

Notwithstanding the high expectations of the advantages of this new method of generating steam, the experiments have not proved so successful as to warrant its adoption; arising chiefly from the difficulty of keeping up sufficient heat to convert all the water injected into it, into steam, and the consequent ejection of the water left in the chamber with the steam, into the cylinder of the engine.

Patent Steam Engine Boiler, by Mr. John Moore, of Bristol. 1824.

This boiler consists of a series of tubes set up vertically, and arranged in a circle, with their upper ends entering a circular chamber, bent round in a horizontal direction, so as to form a ring, and their lower ends entering a similar ring at bottom. Upon a level with the lower ring or chamber, and within the circle of the vertical tubes, a grating is fixed, for the reception of the fuel. The water is supplied by a reservoir, which is also a large tubular ring, embracing the vertical tubes externally, a little above the middle of their height; from this, the water descends through small pipes, and enters the lower chamber,

which it fills, and rises partly up the vertical tubes; here, being exposed to the fire, steam is produced in the upper part of each tube, and collected in the tubular ring above, from whence it proceeds by a pipe to the engine. In case the ebullition in the pipes should throw any water into the upper chamber, connecting pipes, between that vessel and the reservoir, are employed to carry it back to the latter.

The position of the vertical pipes is very unfavourable for the generation of steam, as heat is communicated but very feebly in a lateral direction. The other arrangements are judiciously contrived.

Patent Revolving Steam Boilers, by Mr. Thompson, of Chelsea Steel Works, and Mr. Barr, of Halesowen, Staffordshire. 1825.

The patentees describe their invention to consist in causing the boilers, or steam generators, *to revolve* in a furnace, so that nearly the whole of their surfaces may be equally exposed to the direct action of the fire, and by those means produce a uniform heat to the water, and an equal expansion of the metal with which the vessels are constructed. In the drawings attached to the specification, the most approved arrangement on the rotary principle is exhibited, but as it is capable of being easily explained without any such illustration, we shall dispense with the use of it.

Four cylindrical vessels are placed horizontally and equi-distant over the fuel, in the midst of a furnace adapted to receive them; each of these cylinders is provided with axles or pivots, which pass through the walls of the furnace, and turn upon bearings on the outside; each of these axles carries a small spar-wheel, and motion is communicated to them all by a fifth tooth-wheel, upon a separate axis, situated centrically between the four described. The axis of the central wheel is put in motion by gearing of the ordinary kind, in connexion with the steam engine.

The boilers are supplied with water from one end of

their respective axes (made hollow for that purpose), by means of a forcing pump; the escape of which, during its transmission, is prevented by stuffing-boxes, containing a valve opening inwards, which the expansive force of the steam keeps shut, except at the moment that the superior power of the pump injects a portion of water. The steam, as it is generated in each cylinder, passes off at the opposite extremity to that where the water enters; that is, through the opposite hollow axes, and enters a vessel, from whence it is delivered to the engine in the usual manner. The patentees state that, by their apparatus, "the quantity of steam produced by the same portion of fuel, will be found much greater than by any means yet employed for the generation of steam."

With respect to the fuel, this plan is probably an economical one, but the cost of the erection of such a boiler, and its complex structure, must prove a great drawback to its utility. The method of injecting the water, failed in M'Curdy's boiler, and has of course in this also. Another objection to it is, the great difficulty of keeping the vessels steam-tight at their hollow axes: to prevent the escape of steam, the stuffing-boxes must press hardly upon the axis, the friction of which and the cog-wheels, together with the great weight kept in motion, must subtract largely from the power of the engine.

Mr. J. Bellingham's method of generating Steam, by the burning of Tar under the Boiler. 1824.

In a letter inserted in the Register of Arts, it is stated that Mr. J. Bellingham had employed the combustion of coal tar very successfully, as an auxiliary with the ordinary fuel, in the production of steam, on board of a steam boat in Ireland. The boiler had a furnace, in which coal was burned as usual, but at the back of the furnace a series of retorts were set in an oven, containing ignited coke, on which was thrown, by jets, a uniform quantity of the tar. The smoke from the coal passed through the retorts, where it was inflamed, and returned through the boiler to the iron flue. The effect of this arrangement is

stated to be "the complete combustion of every particle that escapes combustion in the first fire, as well as the great advantage of burning so much more oxygen, by the increased draught, in consequence of the rarefaction of the air in the red-hot chamber. The stove that contains the hot chambers is encircled by the water in the boiler, as well as the entire of the fire-places, on the same plan as Mr. Williams's steam packets at Liverpool, with only the addition of a second row of fluted cast-iron bars, placed horizontally over the common ones, merely allowing room to charge with coke or coal between, for the tar jet to play upon. The tar is pumped into an air-tight wrought-iron tank, with a small tube from the bottom; the pressure of the air, with a stop-cock and crank worked by the engine, may be regulated to keep a uniform flame diffused all over the inside of the flues. This arrangement prevents the possibility of fire being communicated to any part of the ship. One striking improvement in the above plan is, that all the atmospheric air must pass through the coal, as the stove doors are only opened once in eight hours, to charge with coke, coal, or wood; the jets play through small apertures, and the flues are not chilled, as by the present mode of constantly opening the doors to charge and rake the fire. The labour is so diminished, that one man is quite equal to the management of the largest engine boiler now in use."

The writer also states, that Mr. Bellingham had "discovered that the generation of steam is much accelerated by putting in bundles of straw or sticks into the boiler, but he found that a surface of boards strongly put together, so as to cover the entire water, and float on it by a suspension rod, on the surface, answers better, and prevents the wince and splashing of the water, so injurious in condensing steam. He also recommends casing the boiler with thin boards, and at least five inches deep of charcoal, to husband the heat, and prevent the injurious consequence (from radiation) to goods in the hold of steam vessels. This improvement," the writer says, "will enable a vessel to go to any part of the world, as the coal-

tar will not occupy half the room of coals, and does not cost half the price. Iron tanks of any shape to suit the different parts of a ship, can be made to hold it; and when consumed, the tank can be filled with water, which will in no way alter the trim of the vessel."

The foregoing experiments seem to be well deserving of attention; they were, we believe, made prior to the year 1824, which it is proper to notice, as some part of the suggestions here given, have subsequently formed the groundwork of new patents.

Patent Steam and Gas-generating Apparatus, by Samuel Hall, of Basford, near Nottingham. 1824.

This is an attempt to diminish the quantity of fuel used in the generation of vapour for steam engines, by decomposing the steam in a greater or less degree in its passage from the boiler to the cylinder of an engine, under a pressure superior to that of the atmosphere. "The gases or elastic fluids thus generated," (the specification states,) "occupy a greater space at any given pressure and temperature, than the steam does; and being, for the most part, permanently elastic fluids, they possess the further advantage of being capable of use at a temperature not higher than the atmosphere, if required." Founded upon these principles, the patentee observes, that a variety of apparatus may be constructed to obtain a mechanical power, but the following arrangement is recommended as calculated to answer the intended purpose.

Fig. 1 represents a plan, and fig. 2 an elevation of the apparatus, part of which is in section. The letters of reference indicate the same parts in each. A A are two furnaces, with a cylindrical boiler surrounding each; B is a cistern to supply water to the boiler, and C a reservoir for the reception of the steam and gases generated. The intention of having two boilers is, that while the furnace of one is being replenished with fuel, the other may be employed in the production of vapour, so as to keep up the supply unremittingly.

The figure of the furnaces is that of a hollow cylinder;

(FIG. 1.)

they are made very strong, and with air-tight joints. The grating on which the fuel rests, is of the shape of a double hopper; it is supplied with coke, or other fuel, through an aperture *d*, at the top of the furnace; the ashes are raked out from underneath, by a properly formed iron passing through the aperture *e*. Both these apertures *d* and *e*, are furnished with large stop-cocks, of sufficient capacity for the reception of the coke, and for the discharge of the ashes and clinkers, as often as may be necessary. The furnace cylinder is by these means kept air-

tight when the cocks are shut. *o o* is a hollow cylindrical vessel encompassing the furnace, of sufficient strength to bear a great pressure of steam; *f* is a pipe, to which is connected a blowing machine, for augmenting the heat in either of the furnaces; the pipe *f* is, therefore, furnished with stop-cocks at *g g*, that either of the fires may be operated upon, which they are alternately, in the process of working the apparatus.

When the water in the boiler is in a state of ebullition, the steam therefrom passes down the pipe *h*, (the stop-cock in it being opened for that purpose,) and enters the furnace through the hopper-formed grate; there ascending through the fuel under intense ignition, it is for the most part decomposed; certain elastic gases are thereby generated, which, together with the undecomposed portion of the steam, proceed along the curved tube *i*, into the strong receiver or reservoir C. In this vessel it is kept under the required pressure for working the engine, to which it is conducted by the pipe *k*.

From the upper and lower parts of the water cistern B, proceed two horizontal pipes *l l*, which enter the upper and lower parts of the boilers, preserving the water in both at the same level, the height of which is regulated by a float; and a force pump *h*, is employed for injecting the water into the cistern, to supply the loss by evaporation.

In order to regulate the pressure of the elastic vapours in the several vessels described, a communication is opened between the reservoir C and the cistern *b*, by means of a short bent tube *r*, which is furnished with a stop-cock, to cut off that communication whenever required.

In setting this apparatus to work, it is directed that the cistern and boiler be filled up to the pipe *l*, as shewn in the engraving; the apertures in the upper and lower parts of the furnaces opened, when ignited coke is to be thrown into the upper ones *d d*; the bellows are now to be worked, and fuel supplied at intervals, until the required heat is obtained. When the steam has acquired the proper height, indicated by the guage, the apertures at the

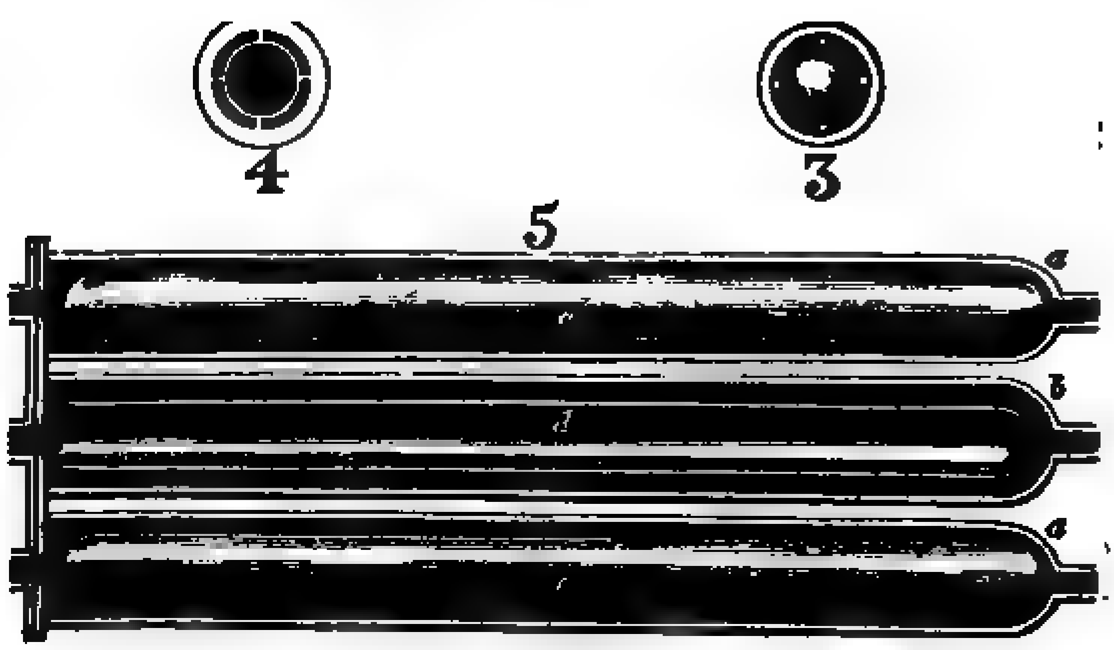
top and bottom of the furnaces are closed by their stop-cocks, also those in pipes *f* and *r*, supposed to have been previously open; the valve or cock in the tube *i* is then opened, along which the steam and gases pass into the reservoir C, and from thence to the engine. When the vapour has continued to pass through the furnace for a certain time, the fire becomes incapable of decomposing a further quantity; the communication with the reservoir C is therefore closed, and the fire replenished with additional fuel and excited by the bellows; while this is going forward in one of the furnaces, the other is proceeding uninterruptedly in the generation of steam and gaseous vapour; and thus the contents of the reservoir are kept under a nearly uniform pressure, and the supply to the engine unremittingly preserved.*

If the patentee has submitted his scheme to actual trial, he has probably discovered that no increase in the elasticity of the steam is obtained by passing it through the furnace. The apparatus appears likewise very defective in its structure, as no means are provided for supplying the fire with a supporter of combustion, after the cocks *d* and *e* are shut. It is, besides, much to be doubted, whether the ignition of the fuel could be preserved even by the alternate use of two furnaces, as described.

Patent Steam-generating Apparatus, by John M'Curdy, of Cecil Street, Strand. 1825.

"My invention of certain improvements in generating steam consists in a new combination of materials, or the adaptation and application of old and well-known substances to produce or effect a particular purpose, which is both novel and useful, and which, from their form, I denominate 'Franklin's Duplex Steam Generators.' For this purpose, I construct one or more vessels or tubes, of any given number, length, or diameter, proportionate to the size of the engine, or quantity of steam wanted, made of wrought or cast-iron, or other material of sufficient

* Register of Arts, vol. iii. p. 52.



strength; which tubes or vessels are closed at both ends, on one end of each of which a head is fixed, that can be taken off at pleasure. Inside of each of these vessels or tubes, I insert, or suspend in the centre, another vessel or tube of still smaller size, of similar materials, leaving a small space on all sides, (varying according to the station they occupy in the furnace, near the fire or more remote), which is thought sufficient for the generators attached to

an engine of the largest size, ***between the outer and inner tubes or vessels.*** The inner tubes or vessels are rendered steam-tight, and closed at both ends, except such number as are placed within the reservoirs or 'steamometers,' as I term them, and which are intended to contain a body of steam for the supply of the engine; or the minor tubes or vessels may be omitted entirely in this combination in the steamometers, or vessels intended to contain the steam. I place these tubes or vessels thus arranged, which I term duplex steam generators, in a common heated furnace, in the same manner as gas retorts, or in the most advantageous manner for heating. The tubes or vessels at the top, or next communicating with the engine, are the most suitable to be reserved for the reservoirs or steamometers, and which I should generally make to contain about ten times the solid contents of the working cylinder of the engine. The outer or exterior vessels or tubes are connected by pipes leading from one to the other, which connecting pipe ought to lead from the upper part of one tube to the upper part of another, through which the steam and water rushes, from the time it is injected by the forcing pump, which I use to supply them with water, till it passes into the steamometer, and from thence through the eduction pipe, which I insert into the ***lower part or bottom*** of the steamometer (whereas, in boilers, the steam is carried out at the top,) into the engine. Into each of the interior tubes or vessels (closed at both ends) may be inserted small pipes, passing from the inner tubes or vessels through the outer ones into the open air, to permit any water or steam that might be forced into the inner tubes or vessels, by the pressure of the steam, to escape. To keep the interior tubes or vessels in their places, and at equal distances from the outer ones, I put around them spiral bands, extending the whole length of the inner tubes or vessels, or rings at intervals, of from one to two feet apart, or pins of the same thickness as the space intended to be preserved as a water line; these rings are grooved all round, or have holes drilled in them, to permit the free passage of the steam and water; and if the

heat should cause the outer tubes or vessels to warp or yield, the same distance will always be preserved between the outer and inner tubes and vessels, and also prevent them from coming in contact in any part. A number of the 'duplex generators' may also be connected with the common boiler, for the generation of steam, the water being forced through them by the pump, and discharging into the steam chamber of the boiler, instead of the steamometer."

In the preceding engravings, fig. 1 represents a front view of a furnace containing five "duplex generators," 1, 2, 3, 4, 5, and one "steamometer," 6. Fig. 2, is a view of the opposite end of the same furnace, with the cast-iron plate which encases it broken away, to shew the interior of the furnace, the hemispherical ends of the tubes, the communication from one to the other, by means of short bent pipes, and the manner in which the fire acts upon them, when so placed; the letters of reference designating the same parts in this figure as in all the others. Fig. 3, represents *a cross section of the outer tube* of a "duplex generator," and one of the hemispherical ends of the inner tube, with the space or "water line" between the two, preserved at a uniform distance apart, by the interposition of narrow pieces of metal. Fig. 4, is a front end view of a "steamometer," with the flanch removed. Fig. 5, is a horizontal section of two "duplex generators," and one "steamometer" between them; in the former, the *interior* tubes *c c* are not shown in section, but whole, that it may be seen they are perfectly closed at each end, from which the water is compelled to assume the shape of a hollow cylinder. In the "steamometer" *b*, the interior tube *d* is left open at one end, for the steam to enter and become a reservoir for the supply of the engine. *e* is the water pipe leading to the pump; *f* is the pump; *g* the steam or eduction pipe, leading from the "steamometer" into the engine. The mode of operation is as follows:—each stroke of the pump introduces water into the vessel *a* 1, (by the pipe *e*,) which is forced or distributed around the spaces between the interior and exte-

rior tube, termed the "water line" in all the vessels The steam generated in this first vessel, and the water that remains, is next forced through the connecting pipe into the second vessel a 2; from thence successively through a 3, a 4, and a 5, then into the "steamometer" b, by the end always open; and from thence by the eduction pipe g into the engine. The water injected into the pump at c, has thus, in its passage from the pump to the engine, passed in a thin sheet over a heated surface of many thousand inches, and, consequently, the steam may be generated of a very high pressure with extraordinary rapidity.

The foregoing arrangement, from disposing of the water in "thin sheets," may seem at first to promise great advantages, but an inspection of fig. 2, will, we think, convince the reader, that the greater portion of the heat passes up the chimney, instead of into the water. The complexity of the construction, the liability of deposits, incrustations in the narrow spaces between the cylinders, and the difficulty of cleaning them out, are likewise objections which, we think, will prevent this apparatus from being successfully used in the generation of steam.

Patent Steam-generating Apparatus, by Joseph Eve, of London. 1825.

The intention of the inventor of this apparatus, and the advantages claimed by him as resulting from its arrangements, are the preserving of a constant circulation or current of water throughout the tubes, preventing thereby, in a great measure, their oxidation or burning out; by the great strength of small tubes to resist lateral pressure, affording security against bursting; and by the uniform circulation of the water, rendering but a comparatively small furnace necessary, and the whole apparatus extremely compact. The reader will perceive a great analogy between this invention and that subsequently patented by Mr. Gurney, a description of which is hereafter given. (See Index.)

Figures 1, 2, 3, and 4, exhibit so many different views of the apparatus, including an application of two revol-

(FIG. 3.)

(FIG. 2.)

(FIG. 4.)

ving cocks, to supply the waste of water, in lieu of a forcing pump. Fig. 1, is a side elevation; fig. 2, a vertical section; fig. 3, a front end view; fig. 4, a back end view; the same letters of reference apply to all the figures. *a* represents the lower conduit pipe; *b* the steam receiver; *c c* are two pipes, in which the water descends from the steam receiver to the lower or conduit pipe; *d* is the dome connected with the steam receiver, from which dome the steam enters into the steam pipe *f*, and into the pipe *e*, which latter leads to the safety apparatus. *g g g*, are ten pipes, which communicate with the lower conduit pipe and the upper pipe, or steam receiver. Fig. 2 represents one of these ten sections in front, the manner in which they are formed, and connected with the two horizontal pipes, which latter are shown in section in this figure; *h* and *i* are two valves, the former kept open by its own weight, and the latter floating. With these two valves every section of pipes is provided at its two orifices, where they communicate with the lower conduit and steam-receiving pipe; *p p* is the fire-grate, over the middle of which the smaller combination of pipes is placed; *o o* is an ash-pit; *q* is an end piece, which, being screwed into the lower conduit pipe, admits of the latter being cleaned out whenever required. The number of sections and pipes composing each section, and the manner in which the pipes are bent, are arbitrary.

The apparatus is filled with water through the orifice *o*, shown in fig. 1. The heat of the furnace causes the water to circulate through the tubes, thereby preventing the steam from driving the water out of them, and the rapid oxidation of the metal. The tubes are from one to two inches in diameter, and from an eighth to a quarter of an inch thick; tubes of these dimensions are sufficiently strong to bear the force of steam of the highest pressure. The horizontal pipes are 1¼ inch thick, and 9½ inches diameter; the vertical pipes, three quarters of an inch thick, and 4½ inches diameter.

The valves *h* and *i*, attached to the orifices of each of the section pipes, where they enter into the horizontal

tubes, are placed there in case of a rupture in one of the sections to which they belong; in which case, the unbalanced pressure of steam would force the water so rapidly into the particular section that was ruptured, as to cause the valves to close, thereby preventing any waste of steam, and detaching the ruptured section from the rest of the generator. By this arrangement, the engine need not be stopped, but would only lose so much of its power as the proportion of one section to the remaining sound ones would be. The two large vertical, as well as the two large horizontal tubes, are imbedded in brick-work, and the sections only are exposed to the heat of the fire; therefore no steam will be formed or generated in the former, while the action of the fire will cause the steam and water to ascend rapidly through the small pipes into the steam receiver, while the water therein, being heavier than the water combined with steam in the smaller pipes, will descend through the vertical tubes into the lower conduit tube, thereby causing a continual circulation through all the tubes; the steam will of course accumulate at the top, and through the dome find its way to the steam pipe and safety apparatus. In case the circulation should be too rapid, and to prevent the water being forced into the steam pipe before it descends again through the vertical pipes, a piece of sheet-iron is placed, perforated with small holes similar to a strainer, in the middle of the steam receiver, from end to end. The small pipes in the sections have the peculiar serpentine form given to them, in order to enable the steam to rise to the top more rapidly than the water.

These boilers are supplied with water by means of revolving cocks, as before mentioned, in lieu of the forcing pump, as shewn in fig. 4, where two cocks are represented; *n* is a vessel filled with water, of any convenient shape; one side of which vessel is near the furnace, so as to keep the water warm; this vessel is connected with the generator through a tube entering at *o*, which is shown in section in the drawing; this tube has two revolving cocks, *k* and *i*, with a chamber between them. The cocks are

made to revolve equally by cog-wheels gearing into each other; so that if cock k be open towards the water reservoir, cock i will be closed towards the tube leading to the generator.

The chamber between the cocks will therefore be filled with water through cock k, by that time cock k closes and i opens towards the generator; the water in the chamber will then descend through o into the generator, by its own gravity, and its place be occupied in the chamber by steam from the generator; cock k opens again towards the chamber, and i is closed towards the generator. The steam in the chamber will be condensed by the water now entering, or escape into the water reservoir n; this revolution goes on continually. If water be presented by cock i to the generator, and the said generator should be sufficiently full, in such a case the water will not be received, but remains in the chamber until part or the whole is wanted, the cocks constantly revolving. By this arrangement, the water can be kept constantly at the desired height.

In this apparatus, Mr. Eve has introduced some very novel and interesting combinations, among which, the following seem to be deserving of notice. First, his method of keeping the water circulating throughout the pipes, requiring, in consequence, but a comparatively small furnace, and, by the compactness of the whole apparatus, rendering it suitable to locomotive purposes; secondly, in the invention of the revolving cocks, by which the boiler is fed without loss of steam or power; for it will be observed, that the heat of the steam in the chamber between the cocks is not lost, which, although condensed, enters into the water chamber n; thirdly, the method of cutting off the damaged portion of the tubes, in case of rupture in any of the sections. The mode of communicating the heat laterally is not good, but, under some modifications, it might be made a very efficient apparatus.

(*Patent-Steam Engine Boiler, by W. H. James, of Thavies Inn, Holborn.* 1823.)

We shall just premise the description of this invention by observing, that it is constructed chiefly with the view of applying it to locomotive purposes; our further remarks are reserved for the conclusion of the annexed account of it.

A series of annular tubes, of equal capacity and dia-

meter, are placed side by side, and bolted together, so as to form by their union a long cylindrical boiler; in the centre of which the fire-place is situated. The tubes are individually (in their transverse section) of a square figure; they are made of the best wrought-iron, of such considerable substance and tenacity, as to sustain a *proving* of 4000 lbs. pressure upon the superficial inch; the two flat sides of each ring are turned to smooth level surfaces, so that the junctures may be in all parts perfectly close and uniform. The flat sides of the chambers are connected together by means of long bolts passing through the end plates of the cylinder, where they are screwed up firmly by nuts on the outside. A cylinder of distinct annular tubes being thus formed, a communication from one to the other is opened, by making two perforations in them lengthways of the cylinder; on the upper side for the free passage of the steam, and one on the lower for the free passage of the water.

When it is desired to construct a boiler of still greater power, the patentee effects it by placing two or more series of such tubes concentrically, one within the other; the steam and water passages communicating, so as to form a single vessel of capacity.

The preceding figure 1, represents a longitudinal vertical section of the apparatus, with a double series of annular tubes; and fig. 2 (annexed), a transverse vertical section of the same; the letters of reference in each figure that are alike designating the same parts. Thus *a a a* are the square annular tubes, a section of the whole being shown in fig. 1; while in fig. 2, the entire circles of only two of the tubes (one of each series) are brought into view. The upper perforations, or steam passages, are shown at *b b*, and the lower perforations, or water passages, at *c c*. The water is maintained at a certain level (about that exhibited in fig. 2), by the action of a float in the regulator *d*, which is of a peculiar construction.

The situation of the furnace is obvious in the figures, the bars or grating of which form two inclined planes (as seen by fig. 2). The flames and heated air take the direc-

Fig. 2.

tion shown by the arrows, previously to their being diffused in every part, and the vapour finally escapes downwards, by the chimney or flue *e*. This flue is made to slide in and out of its place; the whole furnace is likewise constructed so that it may be easily drawn out of the cylinder. The entire boiler turns upon an axis, and rests upon rollers fixed in a circular frame or stand. Every tube is furnished with a few shot, mixed with angular pieces of metal, so that when it is desired to cleanse the boiler from any deposition, it is only necessary to draw out the furnace, the chimney tube, and to unscrew the several pipes, when a few turns with a winch causes the shot to roll, and the angular pieces to scour the angular chambers clean; the operation being similar to that of the scouring barrel employed at Birmingham for brightening iron-work.

To prevent the loss of caloric by any considerable radiation through the sides of the boiler, the cylindrical casing to it is made double, of sheet-iron, with the space between the internal and external coats closely filled up with a

mixture of charcoal and clay, or other materials that are slow conductors of heat.

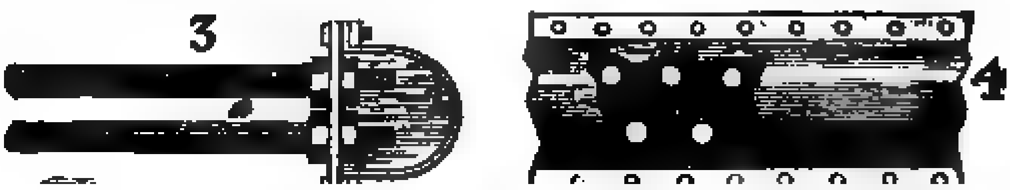
One of the greatest advantages in this boiler consists in its perfect safety, in consequence of its steam reservoir being situated within the generating tubes, which are of immense strength, having, as we understand, been proved to be capable of sustaining a pressure equal to two tons upon the inch. It will be observed also, that by this arrangement of tubes, a very extensive surface is exposed to the action of the fire; and the flue being downward, causes a reverberation of the heat over every part, so that very little escapes misapplied. We have seen a boiler of Mr. James's at work, which contained only a *single* series of annular tubes, instead of the double series we have described, in which perfectly cold water was converted into steam, and blew off at the safety valve, under a pressure of 150 lbs. upon the inch, in the space of fifteen minutes from the time the fire was put into the furnace. The dimensions of this boiler were 20 inches diameter, and three feet six inches long; and it seemed capable of furnishing a uniform supply of steam, equal to at least two horse's power.

Mr. James now makes these boilers of circular tubes, instead of square; they form a very efficient and compact apparatus, economising the fuel considerably, by exposing a very extended surface of metal to a comparatively small quantity of water.

Patent Steam Engine Boiler, by Goldsworthy Gurney, Esq. of Argyle Street, Oxford Street. 1826.

The apparatus delineated in the next page, is identical with that employed by Mr. Gurney in his steam carriage; and Mr. Gordon has applied one of the same kind to his steam carriage, for which purpose the invention seems well adapted.

Fig. 1, shows a vertical section of the boiler. Fig. 2, an external end view of the same. Fig. 3, the manner in which the series of pipes composing the boiler are fixed, and open into the horizontal chambers. Fig. 4, a portion of one of the horizontal chambers partly broken away.



to exhibit the apertures for the pipes, and their arrangement. Similar letters in each figure refer to the same parts.

In the section, fig. 1, the semi-elliptical form in which the pipes are bent, and the manner in which they respectively cross each other, is seen; the ends of these pipes have screw-threads on the outside, to receive nuts, which secure them to the horizontal chambers *b*, as shown at fig. 3. These chambers have also direct communication with one another, by means of the vertical pipes *c*, (figs. 1 and 2); *d d* are two bent tubes, leading from *b b* into the "separators" *e e*, which are tapered cylindrical wrought-iron vessels strengthened by hoops. From 30 to 50 of the pipes *a*, (the number depending upon the size of the apparatus,) are arranged in the manner shown (figs. 1 and 4), in which the fuel is placed as at *h*, the heated air and flames are directed by a bridge *i*, to take the course

delineated, before entering the chimney *k*; but a considerable portion of the heat passes freely between and round about the pipes, the whole being exposed to the powerful effects of a furnace so circumstanced; *o* is the furnace door, and *i* is the ash-pit.

During the working of the engine, the separators *e* are, by the usual means, kept supplied with water up to the level shown, which being higher than the pipes in the furnace, the latter are always kept full of water, a point of essential importance in the opinion of some engineers. The steam generated by the heated pipes in the furnace, is given off in the upper part of the separators, and passing through the pipes *f f*, enters a common pipe *g*, that leads to the engine. Some of Mr. Gurney's boilers have two separators, others only one, dependent upon the size.

The boiler in the preceding diagrams, being such as is used for locomotive purposes, is represented as being surrounded merely by a single case of iron; to prevent the radiation of heat, it is purposed that the casing should be double, with some non-conducting substance placed between the two. For stationary boilers, the iron casings are, of course, dispensed with, and they are set in brick-work, in the usual manner.

To increase the intensity of the fire, the patentee purposes, by some blowing apparatus, to force blasts of air on the top of the fuel, instead of in the midst of it, by which means, it is said, the smoke will be consumed.

To obviate a common objection to tubular boilers, of their becoming choked with a deposition of earthy matters, Mr. Gurney purposes to clean them out, when they become foul, by the following chemical treatment. If the tubes are of *iron*, one part of muriatic acid, with 100 parts of water, are to be left in the boiler a sufficient time to dissolve the incrustation; if of *copper*, the following solution is to be used in a similar way, *viz.* one pound of common salt, half a pound of sulphuric acid, in four gallons of water. To expedite the operation of cleansing, a small fire may be made in the boiler, and the steam be employed to blow the contents out of the tubes. To

avoid incrustations, Mr. Gurney purposes to use only rain or distilled water.

One of the most prominent advantages attending the use of this boiler, is the great facility with which repairs are executed; when a tube is injured or burned, the removing of it, and the substitution of a new one, are not the work of half an hour. Like other tubular boilers, it is safe from the effects of rupture; but the "separator" being in fact a steam reservoir, that part is as liable to explosion as other boilers of the same capacity and thickness of metal. The small tubes exposed to the fire, if always kept full of water, are not likely to be soon burned out. This boiler has, however, its disadvantages, for it will be observed, that the steam is given off above the surface of the water in the separator, which being removed from the fire, and exposed to the cooling influence of the atmosphere, must cause a condensation of the vapour to take place; this appears to be a defect in the arrangement.

Patent Steam-generating Apparatus, by Mr. J. Perkins. London, 1824.

At page 244, Mr. Perkins's former patent for heating water in very strong vessels, under a high state of pressure, has been described. The present invention is constructed with a view to the application of the same principle, but by a totally different mecnanical arrangement, as will be seen by the annexed engraving, which represents a vertical section of the apparatus.

The boilers, or steam generators, as they are called, are in this case very thick cast-iron bars, five inches square, with circular holes perforated longitudinally through them of 1¼ inch diameter, a transverse section of which is exhibited in the figure. They are arranged in three tiers A B D, and are of sufficient length to lie across the furnace, and to pass through the opposite walls, where their extremities are connected together (by means which we shall presently describe,) so as to form one continuous vessel. By the operation of a forcing pump, water is

continually injected into the two upper tiers of generators, so as to keep them always full, and under the pressure of a heavily loaded valve. The lowest tier of generators contain no water, but are kept at a temperature of about 1000° Fahrenheit.

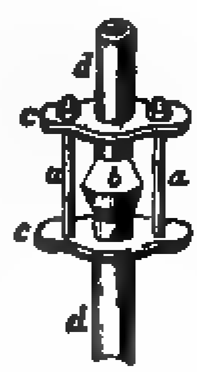
At each stroke of the engine, a certain quantity of water, heated to about 700° or 800° Fahrenheit, is displaced from the two upper tiers, and discharged into the valve box *c*, communicating with the lowest tier, wherein the water instantly flashes into steam; the steam thus formed, passes successively through every pipe in the lowermost range, which is exposed to the strongest action of the fire, before it enters, by a short tube, the safety chamber L, for the supply of the engine, to which it is conveyed by the pipe H. At G is a loaded valve, to

relieve the pressure, should the chamber become overcharged with steam.

The mode of connecting the steam generators together, before alluded to, we will here describe by reference to fig. 2, in the margin; *a a* represent the end pipes, by which those that lie across the furnace are connected together, so as to form one continuous chamber, the apertures in them are formed in the casting, and the parts are brought closely together by an ingenious and strong method, shown on an enlarged scale, in the annexed fig. 3. *b* is a perforated piece of metal, of the figure of two cones, united at their bases, and with their apexes inserted into the pipes *d d*, the ends of which are turned to receive them; *c c* are flanges fixed to the pipes, and connected by regulating screw-bolts *a a*; the latter being turned by a spanner, will obviously press the cones against the orifices of the tubes, and strongly unite them; affording also a ready and convenient means of disuniting them whenever required.

(FIG. 2.)

(FIG. 3.)



Although there are many parts in the foregoing apparatus that are ingenious and useful, there are some deviations from established axioms, that we cannot view in the light of improvements; for instance, Mr. Perkins makes the outsides of his tubes square, which does not increase their strength, while it adds greatly to their weight and cost. The generating tubes are unquestionably safe from explosion; and the mode of generating steam by them is on the same principle as that of his former patent, namely, heating water under great pressure, before allowing it to expand into steam. Mr. Perkins had, in his first apparatus, no steam chamber, because he considered them insecure and unnecessary. Water (he argued) being an incompressible fluid, if a pipe bursts it was only a simple harmless separation of the parts. In this new apparatus,

however, Mr. Perkins has added what he terms "*a safety chamber*," which being in fact a steam chamber, is a misnomer, and, according to his own reasoning, *a danger chamber*. This vessel should be of great thickness, to withstand the enormous pressure to which it is subjected. Mr. Perkins has, unfortunately, not yet demonstrated the advantage of steam at such a great pressure, notwithstanding the numerous ingenious modifications he has made in the apparatus for effecting it.

Patent Steam Engine Boiler, by Mr. John Poole, of Sheffield. 1827.

This invention consists in placing a series of boilers one over the other, in the manner shown in the annexed engraved figure, which represents a vertical section of the apparatus. The water thus distributed presents in the aggregate an increased extent of surface, and consequently, *it is presumed* by the inventor, an increased capability of generating steam, without requiring a corresponding augmentation of the heat, or expenditure of fuel; the series of vessels thus arranged being set in a furnace, and surrounded with a spiral flue, according to the most approved construction.

The specification of this patent is illustrated by four drawings, representing as many modifications of the apparatus; all these are given in perspective outline, together with the method of filling and regulating the supply of water by means of floats, and also by means of the force-pump. As the patentee does not claim these appendages, and as they are well known and in general use, our diagram consists of a single sectional view, which, while it combines the principle of the four perspective drawings, exhibits it in a more palpable manner.

a a a a are four vessels connected together, *b* supply pipe, *c c c* tubes for conducting the water, successively, into the vessels underneath, when it rises above the level shown. To ascertain the depth of water in the lowermost boiler, a pipe and cock must be fixed to it, or some other of the usual means resorted to; *d d d d* are the steam passages from each boiler, and made sufficiently capacious to serve as man-holes, when the boilers have to be cleaned out; *e e e e* are waste pipes, for drawing off the contents of each vessel.

In one of the patentee's drawings is exhibited a method of cleaning the boilers from sediment or incrustation, by the dragging of chains over their bottoms. For this purpose there is a vertical shaft, with four horizontal arms branching from it, one in each boiler, forming the radius of its circle, to which the chains are suspended. Rotary motion being then given to the vertical shaft by suitable gear, the chains scour the bottom of each vessel.

The latter application of drag-chains is common to stills, especially those which are employed by the malt distillers, wherein the grain is distilled in substance. The patentee, however, purposes to apply his invention to stills; but in this respect it possesses no novelty, being almost identical with Saintmarc's patent still (described No. 76, Register of Arts). As a steam-engine boiler, (which is the only light in which it can properly be viewed in this treatise,) the contrivance appears to be new; but then, unfortunately, it possesses no advantage, it being a

very mistaken notion on the part of the patentee, that the extension of the surface of water increases the capacity for generating steam.

2.

3.

4.

(Patent Steam-Boat Boiler, by Mr. James Frazer, of Hounsditch. 1827.

The preceding diagram represents four different views of the apparatus, the examination of which, together with the following explanation, will render its arrangements evident.

Fig. 1, is a front elevation; fig. 2, a transverse vertical section; fig. 3, a longitudinal vertical section; fig. 4, a horizontal section, or plan; the same letters in each figure indicate similar parts. At *a a* are two furnaces and ash-pits, the current of air and flames from which, first proceed horizontally, as shown by the arrows, then descending at *b b*, they unite and take a contrary course in a wider channel *c*, immediately underneath the former, to the front of the boiler; here the current separates, a part going as it were to the right, and a part to the left, into the narrow side-flues *d d*, at the farthest extremity of which *e*, the currents unite again, and proceed by the middle channel *f*, to the front of the boiler, where they ascend into the chimney *g*; *h* is the steam room. The steam pipe, safety valves, man-hole, &c. being the same as in other boilers, it is needless to describe them here.

This boiler being especially designed for the use of steam-boats, no part of the furnace or flue is allowed to come in contact with the wood-work of the vessel, but is wholly surrounded by water; the disposition of the latter in thin layers, divided by long intervening flues, is ingenious, and well calculated to produce steam with rapidity and economy.

Patent Improvements in Steam Boilers, by Anthony Scott, of Southwark Pottery, Durham. 1828.

The advantage attending the employment of good heat-conducting substances, as the materials for the construction of steam boilers, is entirely counteracted when their bottoms and sides become incrusted (as is commonly the case, in a greater or less degree,) with earthy depositions from the water; as such incrustations form a non-conducting shield between the fire and the matter to be heated. To prevent this injurious effect, Mr. Scott places slabs or trays of metal, stone, or wood, near to the bottom of the boiler, which, it is said, so reduces the agitation of the water during the ebullition, that nearly the whole of the sediment descends by its own gravity, and deposits

itself in the trays, instead of on the bottom of the boiler. The transmission of the heat is not intercepted by this arrangement, while the trays are removable at pleasure, for clearing them of the sediment deposited upon them.

Another serious evil results from the incrustations; the heat which the water would take up being intercepted by a non-conducting substance, it acts powerfully upon the substance of the boiler, and the metal is thus, as it is termed, "burnt out." Mr. Scott's trays will in a great measure, if not wholly, prevent this effect taking place.

(FIG. 1.) (FIG. 2.)

Patent Steam Boiler, by Paul Steenstrup, Esq. of Basing-Lane, London. 1828.

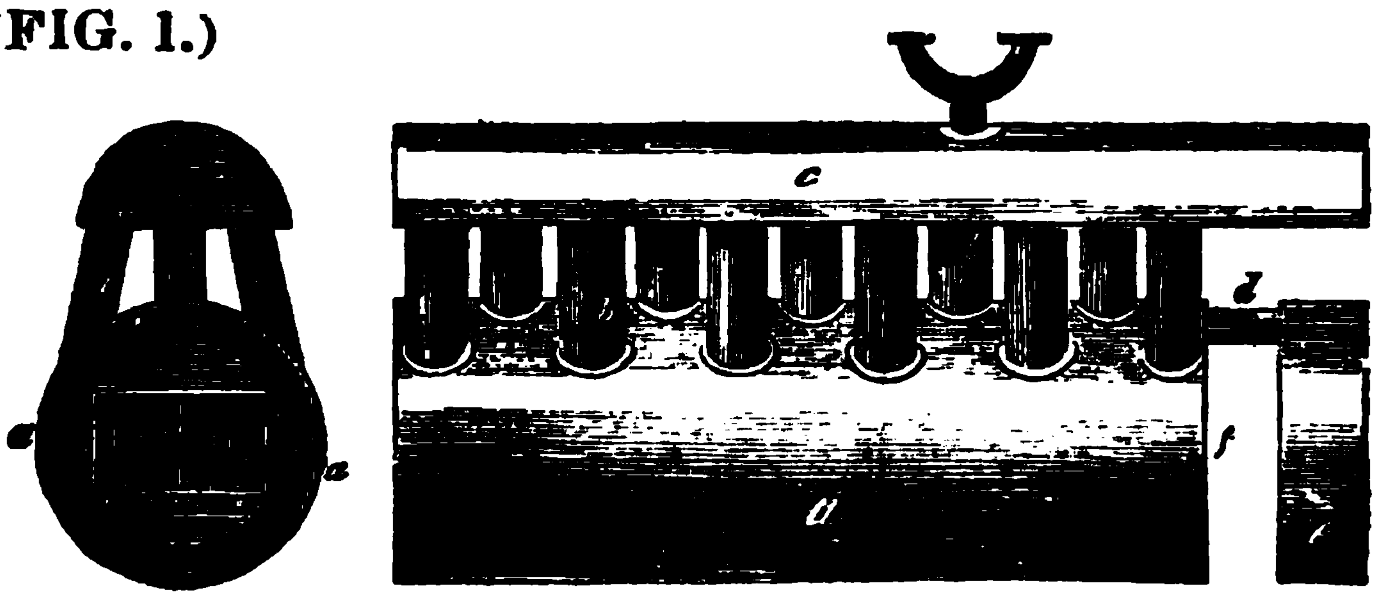
The construction of this boiler, it will be perceived, is much like that of Mr. Frazer's, described at page 403; its arrangements seem to render it more adapted to steam

boats than to other purposes. It consists of an upper and lower chamber, connected together at the sides, and by means of vertical tubes.

Fig. 1, is an end elevation of the boiler; fig. 2, a transverse vertical section; and fig. 3, a longitudinal vertical section: the same letters of reference designating similar parts in each. *a*, is the upper division, or steam chamber; *b*, the lower chamber, connected with the upper by the side chambers, and by vertical tubes, *c c c*, as shown in the sections; *d*, represents the fire bars, on which the fuel is laid; *e*, the bridge; *f*, the ash-pit; *g*, the chimney, which is likewise surrounded with water to economise the heat; *h* is the steam pipe; *k* the man-hole.

The patentee states that this boiler may be adapted to burn any kind of fuel, *i. e.* coke, coal, or wood, by merely shifting the bridge farther back, or advancing it to the fore part of the boiler; also that the tubes *c*, which pass through between the fire bars, will acquire a higher degree of temperature than those near the chimney, and thereby cause an ascending and descending current, which is favourable to the generation of steam.

(FIG. 1.)

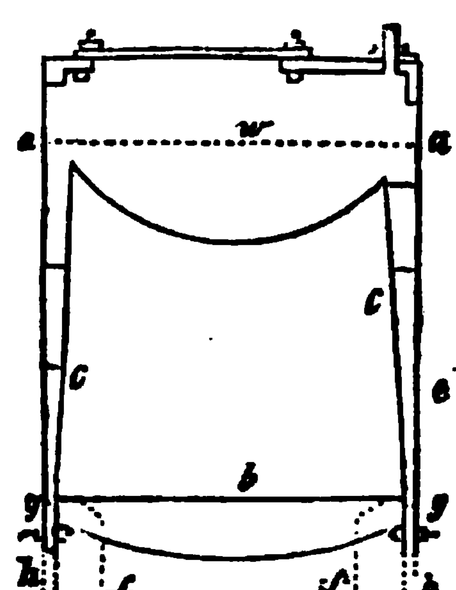


Patent Steam Engine Boiler, by Thomas Tippett, of Gwennap, Cornwall. 1828.

The object of the patentee in this boiler has been similar to that of most of his predecessors, that of exposing as extensive a surface as possible of metal to the influence of the furnace. Fig. 1, represents a front end view, and fig. 2, is

a side view; the same letters of reference in each referring to similar parts. *a*, is a double cylinder, of the usual construction of the cylindrical boiler, the internal cylinder constituting the fire-place and flue. From the external cylinder, which contains water, proceed three rows of open vertical pipes, *b b b*, which support a semi-cylindrical vessel, *c*. At the farthest extremity of the cylinder *a*, proceeds horizontally a short open pipe, *d*, communicating with a small supplementary boiler, which is a cylinder of the same area as *a*, but very short.

This boiler is built in a furnace, in which the flues are so arranged, that the heated air, in passing out at the end *f* of *a*, shall impinge against the vertical side of the supplementary boiler; the flue thence proceeds upward, and along the underneath flat side of the semi-cylindrical vessel, and between the vertical tubes to the front of the boiler; here it descends and passes under *a*, round the back of the supplementary boiler, then rises again over the top of the semi-cylindrical vessel, and proceeds to the chimney, which is in front, nearly over the furnace doors.



Steam Engine Boiler and Furnace, adapted to the use of Anthracite Coal, by S. H. Long, Colonel of Engineers, Philadelphia. 1827.

The description of this invention is extracted from the Franklin Journal, published in Philadelphia, and is the subject of a communication from the inventor, who says:—

"The objects in view are the construction of a boiler, that shall present the largest surface to the action of the heat, with the smallest quantity of water, and such an arrangement of the fire-place, as will subject the fuel to the strongest draught, and, at the same time, apply the largest portion of heat to the production of steam. The manner in which I purpose to accomplish these objects, is as follows:—

"The accompanying figure exhibits a vertical section of the boiler. *a a* represents a cylinder of any convenient dimensions, formed of sheet iron, $\frac{3}{16}$ or $\frac{1}{4}$ inch in thickness, rivetted in the usual manner, and constituting the exterior of the boiler. The head of the boiler is furnished with a *man-hole* and cap, and also with an aperture, through which the steam is to be conveyed to the working cylinder of the engine, *c c*; a conical frustrum, with a concave summit, formed of sheet iron, of the thickness above-mentioned, constituting the interior of the boiler, and at the same time serving as a fire-place. The diameter of its base is about two inches less than that of the cylinder *a*, while that of the summit is about six inches less; so that the thickness of the circular sheet of water contained in the boiler, is one inch only at the bottom, and about three inches at the top of the frustrum, while the depth above the latter does not exceed three inches. The frustrum and cylinder are firmly connected at bottom, by means of a ring, *g g*, of cast iron or other metal, and rivets passing through them respectively. The ring *g g* must extend below the cylinder and frustrum, far enough to receive a flanch or step, for the support of the grates *b*, which are to be adjusted to the circular area of the fire-place. The door is 10 or 12 inches in diameter, through which fuel is to be administered. It is formed by means of a sleeve of sheet iron, firmly rivetted to the cylinder and frustrum, through the sides of which last is a corresponding perforation of the same diameter. The flue proceeds from the side of the upper end of the frustrum, and communicates with the chimney.

"The flue may be constructed in such a manner as to pass

or wind upon the outside of the cylinder, and apply its heat exteriorly to the boiler, and then communicate with the chimney. The boiler may be sheathed on the outside with pine staves, or any other non-conductor.

"The dotted line *w*, represents the surface of the water in the boiler, the space above serving as *steam room.* The tube through which the water is conveyed into the boiler, may enter the latter, at any convenient point below the surface *w*.

"*h h* represents a prolongation of the ring adapted to the use of anthracite, which cannot readily be ignited, in contact with a conductor at a low temperature. The depth of the ring should be about one foot. It must be lined with fire bricks, or lute of suitable thickness, as represented at *f*, *f*, resting upon the grates *i*, or otherwise supported. The fire-place in this instance will be situated below the boiler, and included within the ring *h*. The whole of the heat that may be generated must ascend through the boiler, and a large portion of it be applied to the production of steam.

"The flanch or step for the support of the grates will be circular, and may be inserted within the ring *a*, and sustained by screw bolts or rivets passing through it and the ring, as represented in the figure.

"Any number of boilers, of the description above given, may readily be combined and made subservient to the production of steam, sufficient for the supply of the most powerful engines.

"If we assume three feet for the height of the frustrum, 34 inches for its greatest, and 30 inches for its least diameter; and three feet for the diameter, and four feet for the height of the cylinder *a*; the surface exposed to the action of the heat will be about 28 square feet, nearly equal to that of a locomotive engine of the ordinary construction, while the weight of the water contained in the boiler will be less than one third of that required for the common cylindrical boiler."

The hints herein afforded for the burning of anthracite may prove useful; the arrangement appears good, and a

large surface of boiler is exposed to the action of the fire; it possesses, however, but little novelty, as a very similar contrivance for generating steam was proposed in the Register of Arts, vol. 3, (first series), page 339, which was the subject of a communication to that work by the author of this Appendix, about sixteen months prior to Colonel Long's letter in the Franklin Journal. The plan was to have two cones concentrically placed, the inner cone to constitute the fire-place, with a descending flue, and the space between the inner and outer cone to constitute the boiler.

Self-acting Feeder, for High-pressure Boilers, by R. and W. Franklin, of Tottenham Court Road. 1825.

It is the universal practice to supply the boilers of condensing engines with water, by means of a float; but to the application of a float, in the usual way, to high-pressure boilers, there are two objections. The first, is the inconvenient height of the jack-head, in order to counterbalance the pressure of the steam, (a pressure of 40 pounds on the inch requiring the jack-head to be 70 feet higher than the boiler); the second, is the difficulty of packing the float rod, so as to prevent the escape of steam, and yet allow the rod to move easily, when acted on by so small a force as the hydrostatic weight on the float.

To obviate these difficulties, Mr. Franklin substitutes a heavily loaded valve instead of a high jack-head, and altogether avoids the use of a stuffing-box, by placing the lever of the float within the boiler, as will be seen on reference to the annexed figure, which gives a sectional view of the apparatus as applied to a boiler.

a a shows a portion of the upper part of a boiler, *b* the man hole, *c* the level of the water in the boiler, *d* a lever suspended by an arm to the top of the boiler, and having the float *e* at one end, and the counterpoise *f* at the other; *g* is a rod of half-inch round iron, connected with that arm of the lever which carries the counterpoise; it passes

through the guide or ring *i*, which is rivetted to the feed pipe *k*, and is attached at bottom to a round flat disc *h*.

The feed pipe *k*, is long enough to have its orifice always below the level of the water *c*; its upper end is closed by the valve *l*, and to the bottom of the valve is screwed a long tail or spindle, which, when the valve is shut, descends below the opening of the feed pipe, and almost rests upon the plate or disc. As the water lowers by evaporation, the float end of the lever descends, and the opposite end rises; the consequence of this will be to raise the end *g*, to bring the plate *h* in contact with the end of the spindle of the valve *l*, and thus to raise the valve itself, and open the feed pipe, as represented in the figure. The box *m*, having been previously filled with water by means of the forcing pump, at the end of the service pipe *n n*, (not shown), all reflux of hot water from the boiler is prevented by the valve *o*. As soon as the pressure of the forcing-pump exceeds that of the steam, the valve *o* is lifted, and water passes through the pipe *n*, into the box *m*, and thence down the feed pipe *k*, into the boiler; the valve *l*, being prevented from closing by the support which it receives from the plate *h*. As the level of the water in the boiler

rises, the counterpoise end of the lever *d* descends, and with it the rod *g*, the plate *h*, and the valve *l*. In this situation of the machinery, the water delivered by the service pipe raises the valve *m*, passes the box *q*, and flows off by the waste pipe *s*. The valve *p* also acts as a safety-valve to the boiler, its pressure being adjusted by means of the weight on the lever *r*. The working pressure of the steam in the boiler having been determined, the load on the valve *p*, must be greater than this, but less than the power applied to the forcing pump.

This is an ingenious method of regulating the quantity of water supplied by a forcing pump to high-pressure steam boilers, and obtained for its inventors a reward from the Society of Arts, in 1825. The mode of suspending the float lever in the interior of the boiler is deserving of imitation, in low as well as high-pressure boilers.

Method of supplying Boilers, by Mr. Thomas Hall, of Glasgow.

In the year 1822, Mr. Hall introduced a method of supplying steam boilers with water, by which a considerable saving in fuel was effected; amounting in a 60 horse engine (employed at the Glasgow Water Company's works, to which the improvements were applied), to no less than 19 cwt. per day, or about 25 per cent., as was attested by the secretary of the company.

Instead of allowing the admission of a constant supply of water into the boiler, suited to the proportion of steam required, Mr. Hall admits a given quantity at stated times.

The 60 horse engine in question was worked about 17 hours daily, at a speed of 12½ strokes per minute; diameter of the pump, 22 inches; stroke, eight feet; height to which the water is raised by it in the city, 130 feet. This engine was provided with three boilers, each 16 feet 9 inches long, 5 feet 6 inches wide, and 6 feet 1 inch deep. Length of furnace bars, 3 feet 3 inches; width of furnaces, 4 feet 6 inches; declivity, one foot in three. The foregoing

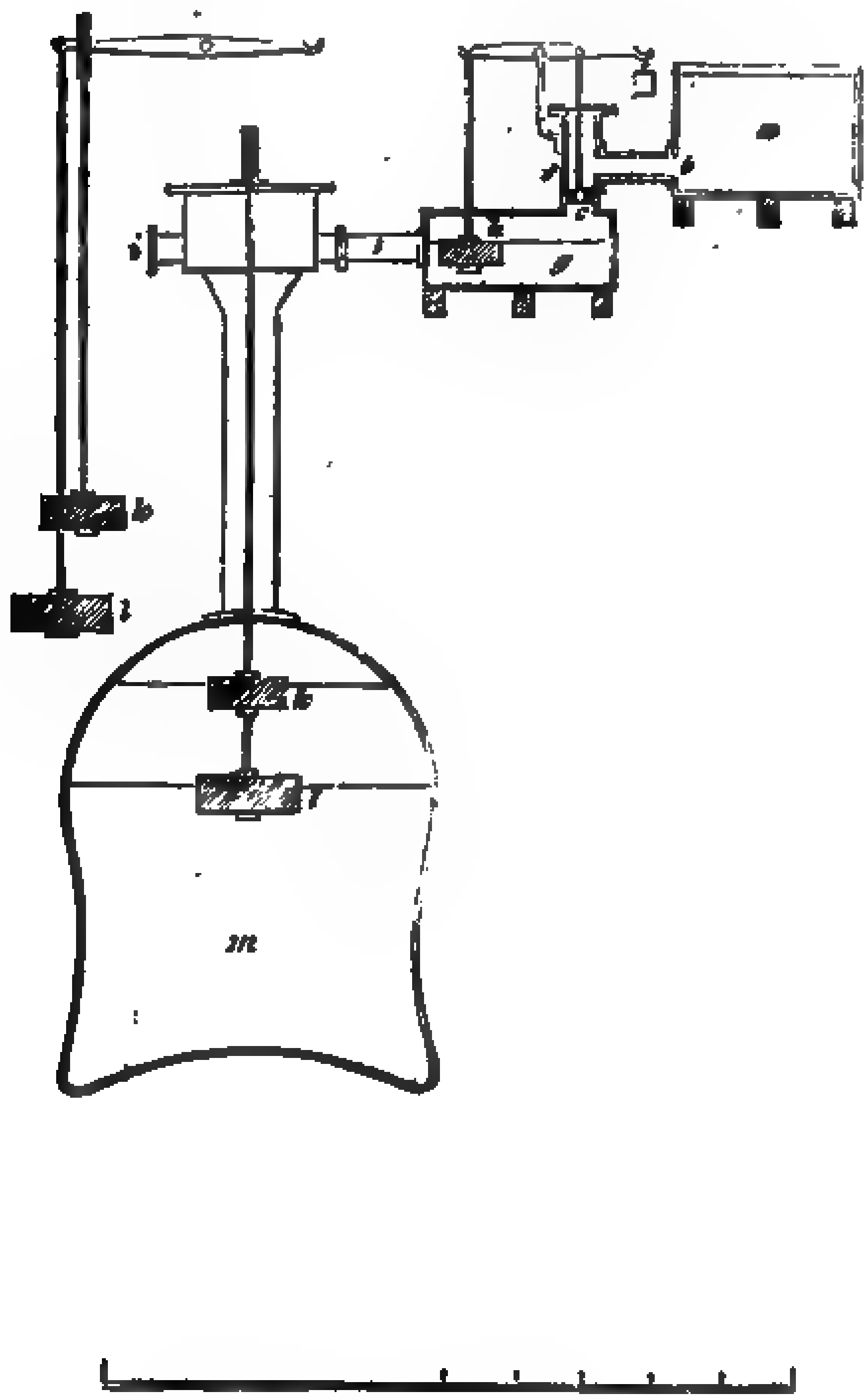
proportions, though admirably adapted for the common mode of working, were found unnecessarily large upon Mr. Hall's plan; accordingly, their dimensions were contracted nearly one fourth, and two boilers alone were found fully adequate to supply the engine with steam; the common height of the water in the boiler, three feet six inches.

When engines are stopped at night, there is always a quantity of fuel left unconsumed, to which more fuel is generally added, in order to have the furnaces in a proper state for starting in the morning. The fire being thus kept up, it is obvious, must cause a considerable reduction of the water in the boiler, so that the engines are again set going, a great deal of water must be let in to supply the loss sustained by evaporation; at which time also, a great addition of fuel, and much care and attention, are requisite. To obviate these disadvantages, Mr. Hall adopted the plan of running in a given quantity of water into the boiler, above the ordinary height at night, which he found might be done quite safely, in boilers of the above size, to the extent of 18 inches. To prevent the danger of overfilling, or the inconvenience of not introducing a sufficient quantity, Mr. Hall placed another float in the boiler, above that in general use, which completely answered the purpose. This second float he fixed at the distance of 18 inches from the first, and counterpoised it by a weight under the common one.

k l, figs. 1 and 2, represent the two floats in the boiler *m*, with their respective counterpoises *n o*. By removing the weight *n*, the floats descend, and consequently open the feeding valve *p*, fig. 2; water being then admitted by turning the stop-cock, the feeding of the boiler goes on, till the water having reached the upper float, it gradually ascends and shuts the feeding valve, thereby preventing the admission of water beyond the height already stated, and requiring also the instant shutting of the stop-cock, neglecting which would occasion waste of water, by overflowing the damper-pipes.

Mr. Hall states that he was next led to the invention of

(FIG. 3.) (FIG. 1.)



(FIG. 2.)

the small cistern g, fig. 1; this be placed on a level with the top of the feeding pipe, with which it communicates by the conduit pipe i i. On the top of this cistern is a valve c, rendered self-acting by means of a float h, suspended from the lever e, and counterpoised by the weight d. The action of this apparatus is as follows:—when the engine is stopped for the night, all that is necessary is the removal of the counter weight n, fig. 2, on which the feeding valve p instantly opens, from the descent of the

compound float *k l*; the water then floats along the conduit pipe *i i*, from the cistern *g*, causes the falling of the float *h*, the consequent opening of the valve *c*, and the admission of the water from the main cistern *a*, by the pipe *b*. A constant supply is thus kept flowing into the boiler, until by the ascent of the water to the line parallel with the float *k*, fig. 1, the feeding valve is shut; the water however continuing to flow into the small cistern *g*, raises the float *h*, which shuts off the communication with the pipe *b*, by the valve *c*. The feeding of the boilers is thus managed with great simplicity and certainty, the waste of water completely prevented, and attendance of the stop-cock rendered unnecessary. By suspending the lower counterweight in its place, at the time of setting the engines to work, the further ingress of water is stopped, this extra 18 inches being found sufficient to work the engine nearly six hours. The running in of a large quantity of water at this time, as well as the care and attention required to be paid to the firing, on the ordinary mode of feeding, are also dispensed with. It has been stated that the quantity of water admitted into the boiler at night, beyond the common height, is 18 inches; this addition, however, from the heat of the furnaces, soon attains a state of ebullition, and a consequent diminution. Here the utility of the self-acting valves in the cistern will be evident, as whatever waste takes place in the boiler is thereby completely provided for. By the single process of admitting this more than ordinary height of water at night, from eight to ten hundred weight of fuel is saved. Where engines cannot, from the nature of the work, be conveniently stopped during the day, the saving from the filling at night only can be obtained; for the weight *n* being an exact counterpoise to the upper float *k*, so soon as the water in the boiler has decreased beyond 18 inches, the under float comes into action, the same as if the other had not been in use, and feeds the boiler in the common way. But where engines can at any time be stopped, to allow the introduction of a given height of water into the boiler, the great advantage of

doing so will be apparent. The waste of fuel during this operation is rendered quite trifling, the dampers being confined somewhat below the working point, by means of a hook and chain. A further saving of nearly five hundred weight is obtained by this second filling, and a third suffices for the day's work of 17 hours, in the 60 horse engine before mentioned, when the same result is produced, completing a saving of nearly a ton of fuel per day, or 25 per cent.

The saving in fuel might be carried to a still greater extent, if the main cistern, *a*, were placed in a convenient situation to receive the warm water from the engine, and if steam-engine boilers in general were made sufficiently large to allow the admission at night of the requisite quantity of water for the ensuing day's work, particularly where engines cannot be stopped during the day.

The diagram fig. 3, shows the floats, and the manner of fixing them to any given height by the sliding rod, attached to the same lever as the common float. The utility of this invention will be evident in those works where engines are stopped at meal hours, or any other time; as, whatever quantity of water may be required to be run into the boiler, all the fireman has to do, is simply to remove the counterweight *n*, and fix the float *k* to the height required.

The following is a comparative statement of the actual consumption of fuel, on the old and new modes of working the 60 horse engine of the Glasgow Water Works, as attested by the secretary of the company.

	Tons.	Cwt.		Tons.	Cwt.
One week's consumption upon the old mode	24	8	Ashes	1	16
Ditto, on Mr. Hall's new mode............	18	12	Ditto	1	4
	5	12			12

Equal to about 19 hundred weight less per day, and two hundred weight less ashes.

In concluding this part of our subject, we have the pleasure to state, that a very important improvement has been made to steam boilers, applicable to all forms, including those of the tubular kind, which will entirely

prevent the incrustation of deposits, and will enable boilers to be cleaned out at any time, without stopping the engines. We are not permitted to say more, as the invention is not yet secured by the sealing of the patent.

SETTING OF STEAM BOILERS.

In the setting of steam boilers, the usual width left for the side flues is nine inches; the object of which has been to allow sufficient room for the passage of a sweeping boy to clear them of the soot. In some instances, however, this width has been reduced to four or five inches, and mechanical means resorted to for sweeping them. A double advantage results from this improvement, *viz.* a considerable saving of fuel is effected, and the degrading employment of the chimneysweep superseded. The flues will require sweeping more frequently, by their being contracted in their dimensions, but by the removal of a brick, or a plug or two, and the insertion of long-handled brushes, it is easily effected.

SAFETY VALVES.

It would be needless to expatiate on the importance of safety valves to the steam engine, since the term itself conveys to the mind not only their importance, but their necessity. The invention was first introduced by Dr. Papin, in 1684, as an appendage to his apparatus for dissolving bones by steam at a high pressure; but to Savery is due the merit of first applying it to the steam engine. It afterwards received some improvement in its form by Beighton, since which time (1718) the apparatus has remained unaltered in its form; and its denomination, the *Steelyard safety valve*, (which it received in consequence of its resemblance to the ancient weighing machine,) remains the same.

Safety valves are popularly considered as only applied to give vent to the steam, when its force becomes *too great* for the strength of the boiler to sustain, without the risk of bursting; but there is another kind of safety valve, of precisely the reverse description; which provides for the

.ety of the boiler, if the pressure in it should become *too little* to support the pressure of the atmosphere, in which case the boiler would be crushed. The latter are called, by engineers, internal safety valves, in contradistinction to those of the usual description, termed *external* safety valves; the internal, however, being only used in very large, and, consequently, weak boilers, are seldom required; we shall therefore briefly state, that they usually consist of an inverted conical plug, kept in its seat by a lever, loaded with a weight, which will be counterbalanced by the pressure of the atmosphere, when the latter exceeds, by three or four pounds per superficial inch, the pressure of the steam in the boiler.

Of the external safety valves, the steelyard form of Papin and Beighton is almost universal; and as it has been frequently introduced in the former pages of this work, we shall not here repeat the description, but merely make a few remarks on the regulations which ought to be observed in its use.

The valve should be always kept inclosed in a box, with a pipe leading to the chimney to carry off the steam that escapes; the box should be kept locked, and the key in the proprietor's pocket or charge, in order that the loading of the valve should not be placed at the discretion of an ignorant or injudicious attendant; numerous dreadful accidents have occurred from the mismanagement of the safety valve, and it has been averred that some explosions have originated by persons maliciously overloading the safety valve.

It is not uncommon in low-pressure boilers to place the whole load directly upon the valve, instead of increasing the force of the weight by leverage: and it is, unquestionably, the safest arrangement, wherever valves are exposed to the interference of improper persons; but it is better in all cases to inclose them. The load per inch on the valve should only just exceed the force of steam per inch required to work the engine; and the orifice opened should, in all cases, be so large as to permit the steam to escape faster than it can be generated.

Fusible metal plugs have been proposed as an additional precaution to the use of safety valves. The suggestion originated with Trevithick, who had holes drilled in the sides of his high-pressure cylindrical boilers, just below the water line, in which the plugs were inserted; so that, should the water, from any accidental circumstance, sink below its proper level, and endanger the explosion of the boiler, by the sides becoming intensely heated, the plugs would melt, and allow the steam and explosive gases to escape. They have also been recommended to be put into the bottoms of the boilers, in order that, if the boiler should become dry, the plug should fuse, and the fire be put out by the discharge of the steam into the furnace.

Some manufacturers introduce two safety valves to a boiler, one of them loaded with a less weight than the other, in order to give timely notice of the excess of pressure, as well as with the view of increasing the security, should one of the valves, owing to corrosion, stick in its seat, or fail to act properly, from any other cause.

The mercurial gauge is another great security to a boiler, as it always indicates the exact pressure; and should the force of the steam increase beyond the range of the gauge, so as to endanger the security of the boiler, the mercury is forced out of the tube into a vessel placed to receive it, and the steam escapes up the tube into the atmosphere. The weight of the mercury might be made to depress the power end of a long lever of the first class, by attaching the receiver to it, whose other end might raise a valve loaded with a weight greater than the pressure of the steam which ejected the column of mercury out of the tube; the valve would thus be kept open, and afford a great additional security to the boiler; or, the depression of the lever by the mercury, might be made to ring a bell to call attention to the circumstance; or to damp the fire, by shutting off the supply of air, and by various obvious means be made to check the too rapid generation of steam.

Instead of the conical plugs usually employed in safety valves, Mr. Woolfe has introduced very generally into

his boilers plugs of a cylindrical form. The cylinder, which fits easily into an aperture in the top of the boiler, has three longitudinal grooves; the steam passes up these, and pressing against the under surface of the head, raises the plug, and allows the steam to escape. The plug is loaded, either by a weight suspended to it inside the boiler, by weights laid directly upon the top, or by the agency of a loaded lever.

We shall now proceed to describe several new forms of safety valves that have recently been published in the scientific journals, and which have been successfully brought into use.

Self-acting Safety Valve, by Benjamin Hicks, of Bolton, Lancashire. 1822.

This invention was described by Mr. Hicks (of the Steam Engine Manufactory, at Bolton), in a letter to the editor of the Leeds Mercury. The writer states that it is not, strictly speaking, his invention, but rather his application of it to a new purpose, and that a similar valve had been used as a clack for a pump, upwards of a hundred years ago. He observes, that he has had a valve of the kind in use for upwards of four years, and is of opinion that it is scarcely possible for an accident to take place in a boiler provided with one.

The opening in the lower part of the box (which is fixed on the boiler top, or, if more conveniently, in any part of a pipe having a free communication with it,) requires to be of such a size as to allow a free discharge of all the steam the boiler is capable of generating. This opening is covered with a spherical valve, (which is made of lead and covered with brass,) of such a weight as to press with as many pounds per square inch, as the pressure of the steam in the boiler at its maximum. The projections are merely to prevent the ball from falling off its seat.

It is obvious that this valve works with very little friction, and, requiring no attention, may be entirely secured from the interference of careless attendants, and a pipe may be attached to the branch of the box, and carried into the chimney. Mr. Hicks recommends this valve, not as a substitute for the ordinary safety valve, but, in all cases, in addition, and so loaded as only to be brought into action at a very trifling additional pressure above that to which the other is subjected.*

This valve would be found of great service in preventing the boiling over of the feed pipes of boilers, when the rooms over them are used as drying stoves in printing works, bleaching works, &c.

Patent Safety Apparatus, by Joseph Eve, of London. 1825.

At page 386, a description is given of Mr. Eve's tubular boiler, to which this safety apparatus is provided; but it is equally applicable to any other boiler, whether of high or low pressure.

Fig. 1, shows a vertical section of a compound tube; *a* is a piston rod, screwed into a piston *b*, fitting a hollow cylinder *e*, which is screwed at its base into the steam receiver or boiler. *o* is a hole perforated through *b*, to allow the steam to ascend into the hollow space above the piston, so that the pressure is equal on both sides, with the exception of the piston rod, the diameter of

* Register of Arts, vol. iv. p. 341.

(FIG. 1.) (FIG. 4.)

(FIG. 3.)

which alone is unbalanced. The piece *h h*, screwed into the upper part of the tube *e*, prevents the steam from ascending higher; another piece *g g*, having a hollow space in the top, is screwed into *h*. Both these pieces have a hole bored in their centres lengthways, of a diameter equal to the piston rod *a*, and to allow it to work up and down. The hollow space in the middle of the two pieces *g* and *h* is filled with packing, so as to prevent any escape of the steam lengthways of the piston rod. The cup *p*, at top, is filled with oil; *k k* is a basin containing water, to keep the upper part cool; the weights with which the apparatus are loaded are placed at *m*.

The hollow tube *e* has longitudinal openings, as represented in fig. 4, (which is an external view of it,) and through these openings the steam escapes, whenever the piston *b* rises.

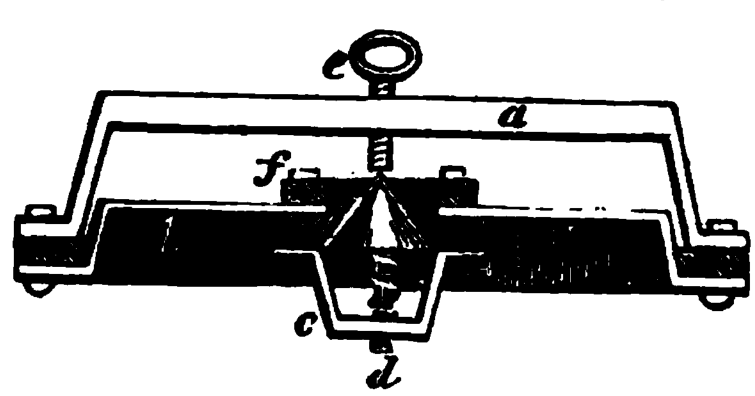
Fig. 2 represents a jacket, which fits over the tube *e*, it has likewise the same number of longitudinal holes cut

through it, and slides over the said tube; by adjusting this jacket, the channel for the escape of steam can be made narrower, accordingly as it may be desirable to raise the piston more or less. The hollow vessel *l*, is fixed over the lower part of the apparatus, so as to intercept the steam from the upper part of it, when the rod is loaded. The pipe *q*, leads from the hollow vessel *l*, to the condenser, or serves for the escape of steam.

Fig. 3 presents an outside view of the piston; *a* is the rod; *c c* packing rings, two on the upper side and two on the lower; these rings press against the tube *e*, keeping it steam-tight, so as to admit none to escape by the longitudinal openings; *d d* are two pieces of metal screwed on at the top and base of the piston, to confine the packing rings.*

Safety Valve, by Mr. C. Sockl, of Royal Row, Lambeth. 1825.

The inventor of this contrivance was rewarded by the Society of Arts for the invention. It appears to be calculated to afford very great security, and, in the opinion of the inventor, is peculiarly applicable to steam boilers on board of vessels.



Instead of the solid lid which covers the main hole, a copper plate or dish is to be substituted, as shown in the above figure. *b* is the copper dish, surrounded by a ring of the same, by which the plate is firmly screwed down upon the rim of the main hole. In the middle of the plate is fixed the valve, of which *f* is the collar, made of

* Register of Arts, vol. iv. p. 87.

iron or brass; *d* the plug, which is ground air-tight into the collar, and is kept in its place by the spiral spring which surrounds its stem, and the stay *e*: over the whole is fixed a strong cross-piece *a*, which is firmly screwed down upon the ring that secures the plate *b*. In the cross-piece works the regulating screw *c*, which may be screwed down upon the head of the plug.

The operation of the valve is easy to understand. *b*, the plate or dish, is only one-fourth or one-third the thickness of the other parts of the boiler; it will not afford the same resistance to the steam: when this, therefore, gets beyond the ordinary pressure, it will cause the plate to become somewhat convex, and will thus leave a clear space between the collar *f* and the conical plug *d*, for the steam to escape; as soon as the power diminishes, the plate will, by its elasticity, return to its former place, and by closing down upon the plug, prevent any further escape of steam.

The object of this valve is not so much to regulate the working pressure of the steam, as to act in aid of the common valve, by affording an additional aperture in case the steam should acquire a dangerous degree of force. It differs from the plug-valves in common use in this circumstance, namely, that in the latter the plug rises out of its socket, in order to allow a vent for the steam, whereas, in Mr. Sockl's, the socket rises away from the plug. The chief advantage resulting from this is, that if any adhesion should have taken place between the plug and the socket, it is more likely to be overcome, on account of the great surface of the socket with its attached copper-plate, which is exposed to the action of the steam.*

* Transactions of the Society of Arts

SECTION III.

ON THE PROPORTIONS OF THE PARTS OF ENGINES, THEIR CONSTRUCTION AND ARRANGEMENT.

In the former part of this work, a considerable number of engines have been described, comprising most of the variations, either in the form or principles of the machine, which have been designed up to the present time. Having thus shown the various parts in their combined state, we purpose describing the constituent parts separately, in their most approved forms and arrangements; to which we shall add some rules for the proportions, selected from the best authorities. But as our limits will not allow us to describe particularly each class, we shall confine ourselves to that which is mostly used to drive machinery in general, namely, the double-acting condensing engine, and according to its arrangement, to act expansively, or at full pressure. Of the other sorts of engines, the non-condensing engine differs only in having fewer parts than condensing engines, and the single-acting and atmospheric engines are employed chiefly in pumping.

We shall begin with the position and proportions of the cylinder, on both which points engineers differ widely among themselves; we shall notice the varieties of their practice, with the most prominent objections to some of the arrangements which have been adopted in this part of the engine.

The positions of the Cylinder—have been varied in all possible ways, either to suit local circumstances, or from the peculiar views of the maker; they have been placed horizontally, obliquely, erectly, inverted, and some have been made to vibrate on arms, and others to revolve.

Horizontal Cylinders.—The principal reasons for placing cylinders horizontally seem to be, that a longer

stroke can be obtained than could be had with the cylinder in any other position, and that they are firmly and readily fixed with but little framing. These circumstances render the horizontal position peculiarly suited for steam boats, where the small height below decks would limit vertical cylinders to very short strokes, and cause the piston to travel more slowly, thereby increasing the loss of power from the reciprocating movements of the machine; and it is of advantage to the stability of a vessel to place the load as low as possible. In mountainous mining countries also, where the transport of ponderous frame-work would be difficult and expensive, these engines offer greater facilities than others for removal.

In an engine constructed by Messrs. Taylor and Martineau, for the Moran Mine, in Mexico, the cylinder was composed of two cylindrical pieces bolted together, and laid horizontally; the diameter was 18 inches, and the length of stroke nine feet, which is the greatest length of stroke, in proportion to the diameter of the piston, we ever met with. But, notwithstanding these advantages, cylinders in a horizontal position are rarely used, even for the purposes already mentioned, for which they seem in many respects so well adapted; the chief objection to them being, that the piston and cylinder wear unequally, owing to the increased friction upon the lower side of the cylinder, and that of the piston by the weight of the latter. A partial remedy for this effect was the subject of a patent to Messrs. Taylor and Martineau, in 1824, (see Register of Arts, vol. iii, page 261,) but we have never seen it applied, owing, we suppose, to the engine being thereby rendered less simple and compact. Long piston rods are objectionable, from their liability to bend in the middle.

Inclined Cylinders.—Mr. Brunel's engine, employed at the Thames Tunnel, (described at page 249,) is an instance of cylinders placed obliquely. This engine was especially designed for steam boats. It is obvious that this position of the cylinder has both the advantages and disadvantages of the horizontal, but each in a less degree.

Erect Cylinders.—By this term is meant those which are placed upright, with the piston rod passing through the top of the cylinder. These are in the most general use, and, unless in peculiar cases, seem to deserve the preference, the wear of the cylinder being more equal, and not so great as in any other position.

Inverted Cylinders.—These are also upright cylinders, but with the piston rod passing out at the lower end of the cylinder. Two instances of this position of the cylinder have fallen under our notice, that struck us as extremely faulty. The first was Mr. Perkins's engine, which was at work a short time in pumping at the St. Katherine's Docks. This was a single-acting engine, working, it was said, with steam at 800 lbs. pressure upon the inch; the cylinder was placed above the fly-wheel, which was of small diameter; the piston rod was of large diameter, in proportion to that of the piston, and the connecting rod very short. The steam was admitted above the piston, and the return stroke was made by the momentum of the fly-wheel against the weight of the piston, connecting rods, &c. in addition to the load, causing a very violent and unequal motion. The other instance was Dr. Alban's engine, set up at the same place, in which the arrangement was equally faulty; the connexion of the fly-wheel was badly contrived, and appeared to have been adopted, because a connecting rod of sufficient length would have required the engine to be elevated to an inconvenient height.

Vibrating Cylinders.—In these the engines are suspended upon hollow arms or trunnions, through which the steam enters and quits the cylinder, and the piston rod is connected directly with the crank, or with a stud on one of the arms of the fly-wheel. Several patents have been obtained for engines on this principle, and a few engines of the kind have been constructed in America, but we cannot see in what their superiority consists, unless it be their greater compactness than other reciprocating engines.

Revolving Cylinders.—In revolving engines, the cylinder is suspended by hollow arms, and is carried round with

the fly-wheel. Several patents have been obtained in this country for engines of this kind, and some have been constructed also in America; but we cannot discover wherein their advantages lie. For an estimate of their merits, see remarks on Witty's engines, pages 211 and 212.

Proportions of the Cylinder.—In the due proportions between the diameter and length, no two makers agree; indeed, from the different proportions met with in different engines by the same maker, it would seem to be a point of no material importance. A patent was taken out by a Mr. Freemantle, for making engines having the length of stroke equal to the diameter, on the ground of such proportions causing the least quantity of friction. In the engine for the Moran mine, it has been seen that the diameter was only one-sixth of the length of the stroke. Mr. Tredgold is of opinion, that if the parts be duly proportioned, and the velocity regulated so as to be equal, the only circumstance necessary to be attended to in the proportions of a cylinder is, that the steam, during its action in the cylinder, should be bounded by the least possible quantity of cooling surface; and as this condition is obtained when the length of the stroke is equal to twice the diameter of the cylinder, he recommends this as the best proportion, in all cases where the space for the engine does not limit the length of the stroke.

Jacket.—To prevent the condensation of steam in the cylinder, it is necessary to keep it as hot as possible; to effect this, Messrs. Bolton and Watt surrounded the working cylinder with a cylindrical case, to which the term *jacket* was applied; between these two there is a narrow space, through which the steam passes in its way to the cylinder; this arrangement has been very generally followed by manufacturers, but we do not perceive that any advantage can be gained by the practice; for it should be considered that the jacket presents a larger surface to the cooling influence of the atmosphere, than the cylinder itself, and, consequently, that it must condense the steam more rapidly. If the jacket be supplied by a separate steam pipe, still the loss from condensation in the jacket

must fully compensate for the greater pressure of the steam in the cylinder. The jacket also adds considerably to the weight of the engine. For these reasons, we think that the jacket might very well be dispensed with. Mr. Tredgold has, we find, anticipated us in recommending an air-tight casing, which would lessen the condensation in the cylinder, make a saving in the expense of fuel, and keep the engine-house cooler.

The following are the contrivances in general use for opening and closing the various steam passages; the first of these which we shall notice is the

Throttle Valve, which is a thin disc placed on the steam pipe, between the boiler and the cylinder; it turns upon a spindle, which is regulated either by hand or by the governor, and may be set so as to intercept a greater or less portion of the steam in its passage, and regulate the supply according to the work.

This valve is never wholly closed during the working of the engine. The above cut represents this valve, and requires no further explanation.

Four-way Cock.—Of the various inventions of admitting the steam to pass to and from the cylinder, the four-way cock is one of the earliest and most simple. It was adopted by Leupold, who first purposed to use high-pressure steam under pistons; and Trevithick, who brought high-pressure engines into use in this country, used a four-way cock to open and shut the steam passages in his locomotive engine. The annexed cut will afford a clear comprehension of its construction. *a* represents the communication with the steam-pipe from the boiler; *b* the passage to the upper side of the piston; *c* the passage to the lower side of the piston; and *d* the passage to the

condenser. In the position represented, the steam is entering the upper part of the cylinder, and the lower part is open to the condenser. If the cock be turned one quarter of a revolution in either direction, *c* will communicate with the steam pipe, and *b* to the condenser.

The four-way cock has been greatly improved by Bramah and by Maudslay, but, under any modification, it has the defect of causing a loss of steam; for not only the steam in the cylinder, but that in the steam passage, passes to the condenser; so that at each double stroke, there is a loss of the whole contents of the steam passage, which, as it is usually equal in area to one-fifth the area of the cylinder, and is of the length of the cylinder, the loss will be one-tenth of the whole quantity of steam required for the cylinder. This loss might however be obviated, by having a separate cock to each end of the cylinder, which would render them very well adapted for small engines.

D *Sliding Valve.*—As the friction of cocks of large diameter is very considerable, sliding valves are more generally used; the simplest is that termed the D slide, from the resemblance of its figure to that letter.

The following cut shows the slide in section; *a* is the steam box, into which the steam is admitted by the passage *b*. The box is bolted to a pipe *c*, formed into three divisions—*d* being the steam passage to the upper side of the piston, *e* to the lower side, and *f* to the condenser; the apertures of these passages are faced with brass, and the space between each opening it is essential should not be less than the opening; *g* is a block of metal, with a recess

cast in it, equal in length to two of the apertures and the space between them; this block is usually faced with brass, and ground upon the pipe *c*, so as to slide over it steam-tight; it is moved by a rod *h*, which passes through a stuffing-box *k*. In this position of the slide, the steam would pass through *d* to the top of the piston; whilst the steam beneath the piston would pass through *e* to the eduction passage *f*. On raising the slide, *d* becomes open to the eduction passage, and *e* to the steam. This slide has the same disadvantage as the four-way cock, in wasting the whole of the steam contained in the steam passages; the apparatus in general use is that termed

Murdock's Slides, invented by William Murdock, of the firm of Bolton, Watt, and Co.; they are represented by the annexed figure.

a represents a portion of the steam cylinder, with its steam jacket *b*, a semi-cylindrical pipe of greater length than the cylinder, and having on its flat side at one end two apertures *c d*, *c* communicating with the upper end of the cylinder, and *d* with the steam jacket; at the lower part is another opening *e*, which communicates with the lower end of the cylinder; these openings are faced with brass ground to a perfect plane. The space between *c d* must not be less than the breadth of one of the openings. An interior pipe of similar form, open at each end, and faced at each extremity with a brass plate of the breadth of one of the openings, is pressed against the apertures in

the exterior pipe or case, by a packing *g*, (regulated by screws *h h*,) at each end; the space between the two packings forming a compartment in which the steam circulates. This slide is moved by a rod passing through a stuffing-box, and, as it is raised and lowered, the steam is admitted alternately to one end of the cylinder, whilst the steam from the other end is passing through the hollow slide, by the eduction pipe *k*, to the condenser: *l* is the throttle valve. These slides being very simple, and not liable to

get out of order, are extensively used, and almost exclusively on board steam vessels.

Conical Valves are, however, the most effective for large engines. These are formed of circular plates of brass, with their edges ground conically, so as to fit into conical brass seats. These valves are generally lifted by rods, working through stuffing-boxes, (see Murray and Wood's valves, page 134.)

When the diameter of these valves exceeds six inches, it requires a great force to overcome the pressure of the steam upon their upper surfaces, when there is a vacuum beneath them. For this inconvenience Mr. Watt devised the following remedy. To the lower side of the valve-box is attached a short cylinder *c*, open at the upper end into *a*, and connected at the lower end with the steam pipe *h*. This cylinder is of the same diameter as the valve *e*, and has a piston *d* connected with the valve *c*, by a rod *f*; *g* represents the opening into the cylinder, and *k* the passage to the eduction valve. If we now suppose there is a vacuum beneath the valve *c*, the piston *d* is pressed upwards, with the same force as *c* is pressed downwards, therefore the pressure upon *c* is thus completely neutralised.

Hornblower's Valves are also designed to effect the same object as the last described; namely, that of diminishing the pressure upon valves of large area. The following represents a section of the contrivance.

a, is a short cylinder, communicating at *b*, with the steam pipe, and at *c* with the cylinder; *d* is a short tube,

having a fillet round its upper edge, which is ground into a conical seat, and its lower edge ground upon a plate *f*, with a conical edge, which is attached to the bottom of *a*; *d* is moved by the rod *g*, passing through a stuffing-box and a guide *h*. On raising *d*, the steam rushes through it into the cylinder. The area of the valve upon which the steam presses, is merely that of the conical seats.

On account of the difficulty of grinding a valve equally into two seats, Mr. Tredgold proposes to remove the upper seat of this valve, and substitute a packing for it, in which the tube *d* shall move.

Dimensions of the steam passages.—There are some variations made by engineers in this respect; it is usual with some to allow one inch square per horse power, for the area of the steam pipes; while others regulate the area of the steam passages at one-fifth of that of the cylinder.

Eccentric Motion.—The opening and closing of the valves are usually effected by the revolution of the fly-wheel. On its axis is placed a circular plate, called the *eccentric*, from its centre not coinciding with that of the axis. The eccentric revolves within a hoop, to which a long rod is attached; and this rod is connected with the levers by which the slides are lifted. But where nozzles are used, the connecting rod gives motion to a spindle, having cams upon it, in which cams the lower ends of the rods, to which the valve rods are connected, rest, and alternately rise and fall with the motion of the spindle.

By means of the eccentric, the opening and closing of the valves are performed by a gentle action, without any shock or striking, which is owing to the uniform, continuous motion of the eccentric; but unless the range of

the valves is greater than the height of the steam passage (which occasions unnecessary friction), they are fully open during only a small portion of the stroke; it has, therefore, been proposed by Mr. Tredgold, to form the eccentric into a ram or tooth. We have seen some instances in which this has been done; one of these is an engine by Fentom and Murray, at the London Dock New Basin.

Modes of Working.—When the steam is open to the end of the stroke, and closed with the eduction valve, it is called *working at full pressure*. It may, however, be cut off at any portion of the stroke, the remainder of the stroke being effected by the expansion of the steam in the cylinder, which is called *working by expansion*, and is the most economical mode.

When engines are worked at full pressure, any of the valves which we have described may be used; but when the steam is worked expansively, the valve motions become somewhat more complicated, as the steam valve is closed at a certain part of the stroke, whilst the eduction valve closes only with the termination of the stroke, and thus two separate motions are required. The conical valves are generally used in this case; each valve being lifted up by a separate rod, moving on separate cams; but Mr. Tredgold, in his work, shows a method of adapting the slides and four-way cocks to expansion engines, by enlarging their range, and moving them at two motions.

Pistons.—There is no part of the steam engine in which good principles of construction, combined with the perfection of workmanship, are so essential to the efficiency of its operations, as the piston. It is not sufficient that its periphery should accurately fit, so as just to touch every part of the internal circumference of the cylinder, but it must possess the property of expansion; otherwise, the attrition upon its surface quickly reduces its dimensions, leaving a space between it and the cylinder, through which a portion of the steam escapes; whereby the impetus given to the piston is not only reduced in proportion to the quantity of steam thus wasted, but the effect of that portion which does not escape, is partially neutralised by the steam acting on both sides of the piston.

The difference of effect between a good and a bad piston has been frequently found to amount to more than half the power of an engine; by which it may become incapable of executing the required work, besides wasting half the quantity of fuel consumed; in many other respects, the evils from the defects of a bad piston are of serious importance.

As the piston has *usually* been made of metallic substances, unalterable by any expansive property therein, it has commonly been *packed* with an external coat of hemp saturated with tallow, in the manner represented by the annexed section.

a is the lower face of the piston, fixed to the piston rod *b*, by its conical end, and by cutter keys; *c* is the upper face of the piston, fixed to the lower by screws *d d*; *e e* show the packing of hemp and tallow filling up the large groove or interstice between the upper and lower discs; this packing presses against the sides of the cylinder, and when it wears away by friction, the screws *d d* are turned, which forces out the packing against the sides of the cylinder; when the packing is entirely worn away, fresh packing is substituted.

Pistons nearly of this kind, packed with hemp or other vegetable substances, were in general use from the time of Papin and Savary to that of the Rev. Edward Cartwright, a period of upwards of one hundred years. The last-mentioned scientific clergyman (who was brother to the late Major Cartwright,) introduced the first expanding metallic piston; an invention of the utmost importance, it being almost indispensable in high-pressure engines, as the hemp and tallow packing is quickly destroyed by the great heat of the steam.

Cartwright's metallic piston, as it was originally constructed, has been already described at page 118; since that time it has received some improved modifications, which will be easily understood by an examination of the annexed figure, after having perused the former description just referred to. *a* is the piston rod, from which radiate a series of spiral springs *b*, that press upon the segments *c c*. In this piston, it will be observed, the segments are closed, until, by the wearing of the cylinder and piston, they open at the joints and diverge by the pressure of the springs, and occupy the enlarged area of the cylinder. The spiral springs are calculated, both by their structure and position, to last longer, and operate with better effect than the feather springs of Mr. Cartwright; nevertheless, these improved pistons had several defects, which much limited their employment; the following is perhaps the most prominent. When the *external* segments wear, and separate by the pressure of the springs, the internal segments also separate from the same cause, but they do not wear; consequently, the circular parts of the internal segments no longer fit the external series, but leave open crevices between them, through which the steam, first entering the external cavities before mentioned, readily finds its way into the interior of the piston, hence it proceeds through similar channels, to the opposite side of the piston. These openings likewise admit sand, which lodges and accumulates in the crevices, until they are blocked up, and the springs cease to act.

Notwithstanding the imperfections of Mr. Cartwright's

pistons, they were the best then known, and were consequently applied, under various modifications, to numerous engines. The happy idea of constructing an expanding metallic piston, is important in another point of view, as it probably was the cause of calling forth the inventive talents of Mr. J. Barton to the subject, who has certainly succeeded in producing a highly-improved combination of parts, by which the objections to the Cartwright piston are completely obviated, and the action may be deemed almost perfect. This piston, under its earliest arrangement of parts, has been described at page 269, but the improved modification now adopted by the inventor, together with the importance of the invention, render a fresh description of it a matter of propriety.

(FIG. 1.)

(FIG. 2.)

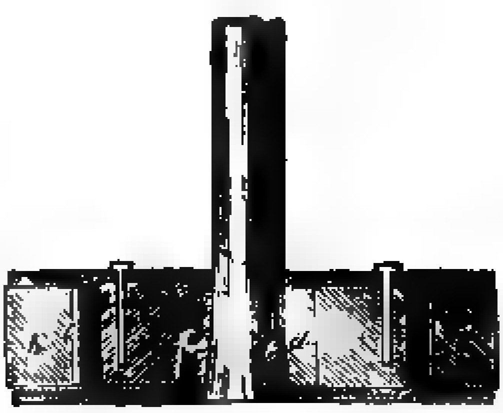


Fig. 1 represents a plan of Mr. Barton's piston, with the top plate removed; fig. 2 is a vertical section of the same, taken in a line with *b e d b* on the plan.

a a a a are the four metal segments; *b b b b* four right-angled wedges interposed between the segments, their points forming a portion of the periphery of the circle; *c c c c* is a thin steel spring, formed into a single broad hoop, and pressed into the undulated form represented, by which it is found to act with uniform energy upon the wedges, until they and the segments become so much worn in the course of time, that the steel spring recovers itself into its original circular figure; *d* is the frame-work, cast

in one piece, with the lower plate of the piston; *e* is the piston rod; the dark spaces shown on the plan within the circular frame *d*, are cavities to lessen the weight of metal; the other dark spaces are cavities to allow of the free action of the circular spring.

To prevent the segments from falling out of their places whilst the piston is being taken out, or put into the cylinder, the periphery of it is grooved near to its upper and lower edge, in which are sunk two slight spring hoops, cleft across into forked joints, which close together simply by their elasticity. To lubricate the piston, there is a third groove, made midway between the two former, for the reception of oil; these parts are not introduced into the figures.

The action is as follows:—as the piston and cylinder wear away by the friction, the circular spring *c*, presses out the wedges *b*, and these project the segments against the cylinder; by degrees they are reduced to the dimensions of that exhibited in the annexed figure, which is an

(FIG. 3.)

exact representation of one that we saw taken out of a cylinder, wherein it had been constantly working (without repairs) for several years.

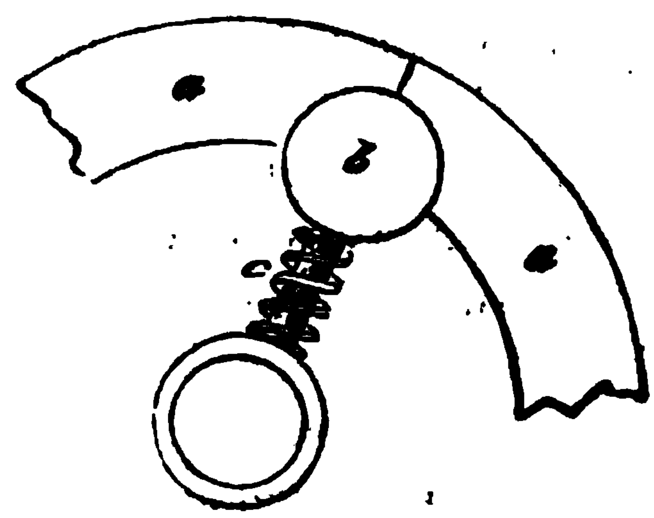
Neither the cylinder nor piston were in the slightest degree grooved or scored, but had both retained their circular figure, and were highly polished on their rubbing surfaces: we say this, as the contrary has been stated, to

Mr. Barton's serious disadvantage. The Repertory of Arts contained a most uncalled-for statement of this kind, from Dr. Gregory, the professor of mathematics at Woolwich, which statement Mr. Barton triumphantly answered, by having his pistons drawn out from the cylinder of an engine in Woolwich Dock-yard, and shown to the doctor.

It is certainly easily demonstrated that the wedges move faster than the segments, and that, consequently, the pressure upon the wedges is greater than that on the segments; in a right-angled wedge this difference is as 2 to 1, but the wearing is in no such proportion, nor is there in practice any perceptible difference at all; which arises, we conjecture, from the following cause. The cylinder being of cast-iron, and the piston of a much softer and easier abraded metal (an alloy of copper), the only effect of the superior pressure of the wedges, is to wear them away quicker than the segments, while the wearing of the cylinder, from its superior hardness, is scarcely perceptible. In consequence of this arrangement, the brass piston will always conform itself to the circular figure of the cylinder, until worn out.

In France and in America, Barton's piston is known only by the name of *Browne's* piston, owing to an American barrister of that name having imported and patented it there as his own invention: it is not only extensively used in those countries, but its benefits have been experienced in almost every part of the world where the steam engine is employed. Notwithstanding these circumstances, there are few inventions of such great utility that have met with so much senseless opposition. To avoid Barton's patent-right, many absurd modifications of his piston have been made, in which it is asserted, in contradistinction to Barton's, that all tendency to score the cylinder is obviated. We purpose describing some of these modifications, not because they possess the least intrinsic merit, but because they have emanated from men of influence or talent, whose errors ought not to pass uncorrected; but we should premise that description by

observing, that Barton's claim to invention consists in *the application of wedges to the projection of the segments* that compose the periphery of the piston, which wedges, on account of their moving through a greater space than the segments, it is asserted, score the cylinders. How these persons get over this assumed difficulty, the reader will observe. The first we shall mention is the modification of Messrs. Hall and Son, who are extensive engineers at Dartford. The annexed diagram shows only a part of their piston, the remainder of the circle being, of course, a continuation of the same arrangement.



a a are metal segments, of which there are four to complete the circle; *b* a cylinder, of which there are also four, placed between the segments; these cylinders are operated upon by spiral springs, which project and press asunder the segments, as they wear away by friction against the cylinder. Upon the segments separating, they leave gaps or open clefts between them, through which the steam would escape, were it not opposed by another and similar series of segments, whose middle parts cover the clefts between the other series, or "break joint." The construction of this piston, it is argued, does not invade Barton's claim,—for this reason, that cylinders are not wedges Now we submit, that the geometrical definition of a wedge has nothing to do with the subject; and that whatever is employed *to wedge*, and *does wedge*, is *a wedge* in practical mechanics, as well as in common sense. Lord Chief Justice Tenterden, however, decided the reverse; he would not allow a jury to consider the point at all, but nonsuited

Barton, who had brought an action against Hall for an infringement of his patent-right.

The disadvantage of employing wedges with curved instead of straight sides, is too evident, upon inspection of the diagram, to need explanation; we shall, therefore, only consider the point as respects the scoring of the cylinder. Admitting the argument to be correct, that the increased friction of certain parts of the circumference beyond that of the others will have the effect stated, it follows that Mr. Hall's will make RIDGES in the cylinder; for where the gaps beforementioned occur, the piston is only half as thick as the other parts; consequently, the decreased friction at the gaps will wear the cylinder less by one half than the other parts, and form projecting ridges.

We shall next describe a piston manufactured by Messrs. Maudslay and Field, known by the name of the expanding ring piston, because this will enable us to rectify two mistakes made by Mr. Tredgold, in his excellent treatise on the Steam Engine; and we cannot but regret that so eminent a writer should have exposed himself to such merited animadversion.

Alluding to Mr. Barton's invention, Mr. Tredgold says, (Art. 470,) "A piston of this kind, and a true cylinder, has been *known to work for some years without requiring any other attention than keeping it properly greased*, yet it is easy to prove that the wedges and segments do not expand equally; hence, in this state it was not applicable to high pressures." We would here inquire, what signifies this petty cavilling about what the wedges and segments do, provided they work well without attention for years? And the assertion that the pistons are inapplicable to high pressures, because of the unequal expansion of the wedges and segments, is universally known to be the very reverse of the fact. We could mention twenty instances where Barton's pistons have been most successfully applied to high pressures for several years continuance; but we will state only one fact, which has in itself the force of a host in disproving Mr. Tredgold's assertion.

In 1823, Mr. Perkins constructed his high-pressure engine, in which he used steam of from 800 to 1000 lbs upon the inch. The piston in the cylinder was the double expanding ring kind, as represented in the annexed perspective sketch.*

It consists of two concentric rings of brass, external diameter five inches. *a* is the inner ring, to which is screwed, from the inside, a bevelled piece of brass *b*, that slides and fits flush with the outer ring *c*. The proportions of the parts being accurately drawn, it will be obvious, from the great thickness of the rings, that they possess but little elasticity, which we have found to be the case on trial. The identical piston described, and now lying before us, came out of the cylinder of an engine manufactured by Maudslay and Co., in which it was afterwards found necessary to substitute Barton's, though the former was not apparently worn; but another piston, of precisely the same construction, was made by Mr. Field, for Mr. Perkins's engine before-mentioned. It was found,

* We have been informed, that a piston exactly of this kind was invented by a Mr. Donkin, at Penzance, in Cornwall, in 1818; and that the invention was repeatedly tried in Wheal Vor Mine, for several years, without success. In 1818, Mr. Field introduced the same invention, and has since applied it to several engines constructed by his firm (Maudslay and Co.) One of these pistons we have in our possession, from which we made the above sketch

upon trial, incapable of standing a day's work, and it scored the cylinder so much, as to render it necessary to have it fresh ground. Barton was then applied to, who made a piston for the engine that acted perfectly, (without leakage,) under the enormous pressure mentioned, for a considerable period, as was certified by Mr. Perkins at the time. Here, therefore, is a successful application of Barton's piston, under a pressure of about 1000 lbs. per inch; notwithstanding which, Mr. Tredgold has stated its inapplicability to high pressures, which are usually only about 40 lbs. to the inch.

In the next page to that last quoted (229), Mr. Tredgold says, "but by combining hardness and elasticity, Barton has done much to render these pistons *tight and durable;* they still, however, chiefly depend upon the skill of the workman; *when* they are done well, by a person who understands them, *they undoubtedly answer effectively*." This observation is about as acute as to say, that "knives are not fit for cutting; but, when they are well sharpened by an experienced cutler, they will cut effectively." The inconsistency of Mr. Tredgold on this sudject is quite remarkable. He admits that these pistons are "tight and durable," that they "answer effectively for years," even without looking at; yet, in the teeth of these admissions, which are apparently wrung from him by facts under his own eyes, he adds, in the very next line, "*To avoid the effect* which the unequal expansion of the parts of Barton's piston produces, I would recommend the construction shown by fig. 7, where the wedge-formed pieces do not extend to the surface of the cylinder; and to prevent there being an aperture at each joint, two series of segments and wedges should be used." We do not give this figure, because it is in every respect the same as Hall's, except that he employs Barton's wedges, in lieu of the ridiculous cylindrical substitute of Hall.

We have now to inquire wherein the advantage of Mr. Tredgold's modification consists. It certainly does not lie in the *simplicity*. Barton has four segments, four wedges, one spring=nine parts; Tredgold has eight seg-

ments, eight wedges, eight springs, eight bolts=32 parts; or nearly quadruple the number of parts to fit and slide over one another, incurring so much more labour and so much more expense to effect it, and, after all, so many more liabilities to derangement. Then, as respects the unjust *insinuation* of Barton's pistons scoring the cylinders, how does Mr. Tredgold proceed to "avoid the effect" he mentions, of the unequal expansion? Evidently, by producing double the friction upon those parts of the piston where the thickness is doubled; and, consequently, of wearing the cylinder into eight *ridges*, where the eight segments divide. Instead of pointing out the blunders of Barton's opponents, the most scientific writer on the steam engine recommends them to the mechanical world as his own invention and improvement!

If Barton's pistons did in reality produce the effects stated, there are some very easy ways of obviating them, without destroying the beautiful simplicity of the inventor's combination. One of them is to make the wedges as obtuse as possible, by which their motion would be brought nearer to an equality with the projection of the segments; this would be only a partial remedy, but we have another to mention that is more complete. It is to make the wedges (if rectangular) of such a metal or alloy as would be abraded by the cylinder twice as fast as the metal of which the segments are made. These remedies for the pretended evil may be employed either singly or combined; but, we dare say, that they have long since occurred to Mr. Barton, but that he has found it unnecessary to resort to them in practice.

In 1821, Mr. E. B. Symes, of Lincoln's Inn, took out a patent for an expanding hydrostatic piston, the specification of which includes the description of several modifications. Those only which can be considered as at all applicable to steam engines, may be described without the aid of explanatory diagrams. In one of them, the piston consists of two plates of metal bolted together, so as to leave a cavity between them; the plates spread out wider apart at their peripheries, round which is securely fastened, to

the top and bottom plates, a strong hempen band, painted on the inside, and of a texture and flexibility similar to the hose of fire engines. The upper plate has an aperture with a screwed cap, through which the lubricating fluid is introduced, so as to fill up the space when the cap is screwed down to confine it. The two plates being now drawn together by screws, the packing will be bulged out at the sides, and press against the surface of the cylinder, which will be lubricated by the grease oozing through. The pressure of the steam will likewise cause the plates to collapse, and produce a similar effect.

Another modification consists in a cast-iron piston, with a hollow piston rod, through which the fluid is introduced from a reservoir at the upper end, and communicates with a large groove made round the periphery of the piston, which is inclosed by a covering of canvas as beforementioned, through which the grease finds its way to lubricate the cylinder. We have never met with the application of these pistons to an engine, and we much doubt their capability to sustain even the work of a low-pressure engine, without some additional packing.

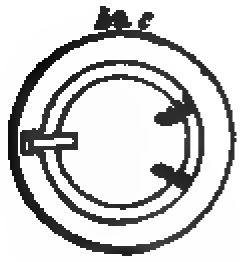
In 1822, Mr. Jacob Perkins included in the specification of a patent, a description of an expanding metallic piston, which he applied to an engine of his own; it did not, we understand, answer his expectations; but as the combinations of such a mechanician as Mr. Perkins will probably interest the reader, we shall introduce a description of it from the Register of Arts, (vol. iii. page 170, First Series.)

The specification of the patent states this to be a new arrangement of rings for metallic stuffing, and to consist in keeping the expanding opening of a flexible ring steam-tight, by means of eccentric and non-expanding rings.

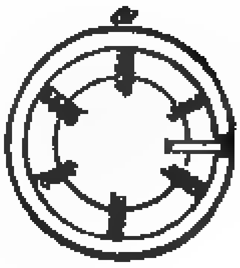
The annexed figures show the arrangement of all the parts of the contrivance.

In the elevation (marked Ele), *a* is a flexible expanding ring, and *b c* two inflexible non-expanding rings. The adjoining figure (marked Sec.) gives a vertical section of the whole of the piston. The figure *a* is a plan of the

b c



a



flexible expanding ring, shown in the elevation and section; and the figure *b c* gives also a plan of the two inflexible rings marked *b c* in the elevation and section.

In the plan *a* of the flexible ring an opening is shown, and to prevent the escape of steam at this opening, the two inflexible rings *b c* are placed one on each side. In the latter, it will be observed, there is a notch, in which a guide pin is fixed, and that there are two heliacal springs which press the side of the ring to which they are attached eccentrically from the piston. When these two rings are fitted on to the piston, the opening in the broad flexible ring *a*, should be placed on the opposite side to that in which the notches in the inflexible rings are placed. By this arrangement, when the piston is put into the cylinder, these two eccentric rings *b* and *c*, will press against that part of the cylinder immediately above and below the opening in the elastic ring *a*, and will thereby supply the deficiency occasioned in the piston by such opening in the elastic ring.

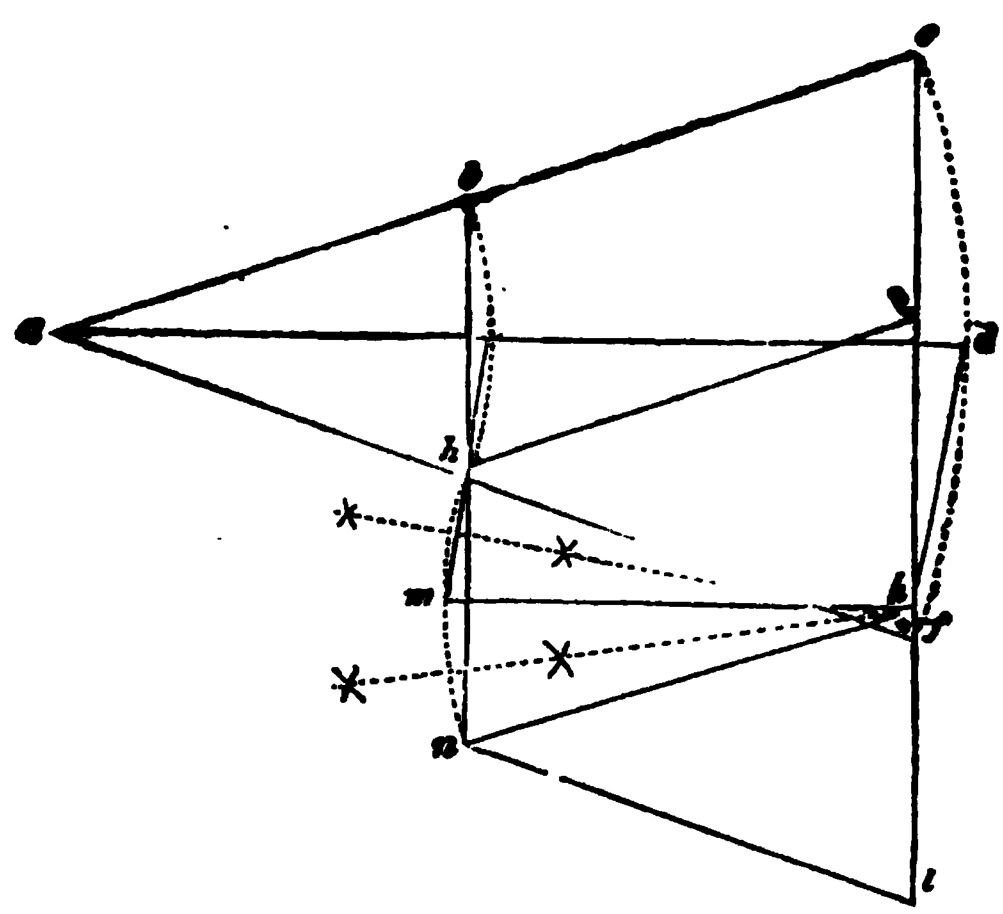
In 1828, Mr. Jessop, of Butterby Hall, near Derby, patented an expanding metallic piston, which has some fair claims to notice, as it may probably, under some slight modifications, be rendered a very efficient instrument; a description of this piston has been given in a former part of this work, page 270.

Expanding metallic pistons have likewise been applied to rotary engines, in which cases they are usually rectangular. Some account of these will be found under their respective engines; the very limited use of these does not, however, render it desirable to extend our observations upon the subject.

Parallel Motion.—We shall now proceed to describe

various methods by which the piston rod is made to move in a right line, whilst the end of the beam with which it is connected describes an arc of a circle. The first plan of Bolton and Watt was to place a toothed sector on the end of the beam, the length of the radius being equal to the distance between the axis of the beam, and a vertical line through the centre of the piston rod; on the upper part of the piston rod was placed a rack, which acted upon the sector, and forming a tangent to it, preserved a rectilinear motion of the piston rod throughout the stroke.

A much superior method was afterwards devised of effecting the same thing, by an arrangement of rods moving in circular arcs; the principle is simply this:—If a bar be so confined by other bars, that the motion of the end *a* in a right line, causes the other end *b*, to describe a certain curve, then, on the other hand, the motion of *b* in the curve will cause *a* to describe a right line.



To apply this to the case before us, et *a b c* represent the beam of an engine at the highest point of the stroke, *a d* its position at the middle of the stroke, and *a f* its lowest position. *c g* and *b h* are two side rods suspending the bar *g h*, parallel to *a b c*; *g k l* a right line, in which the bar at *g* moves in a groove; then, when the end of the

beam c is at d, the end g of the bar $g\ h$ will be at k, and as $g\ h$ is parallel to $a\ d$, the other end h of the bar $g\ h$ will be at m, and when c arrives at f, g will be at l, and h at n; the point h, therefore, will have described a curve, passing through the points $h\ m\ n$, whilst the piston moving in a right line, passed through the points $g\ k\ l$; if, therefore, the groove in which the head of the piston rod moved be taken away, and the end h of the bar $g\ h$ be jointed to a radius bar describing a circular arc passing through the points $h\ m\ n$, then the end g of $g\ h$, to which the piston rod is attached, will move through the points $g\ k\ l$, and the whole path of the piston rod will differ very little from a right line. The small deviation from a right line arises from the circumstance that the curve described by the end h, is not exactly a circular arc, when g moves in a strictly right line.

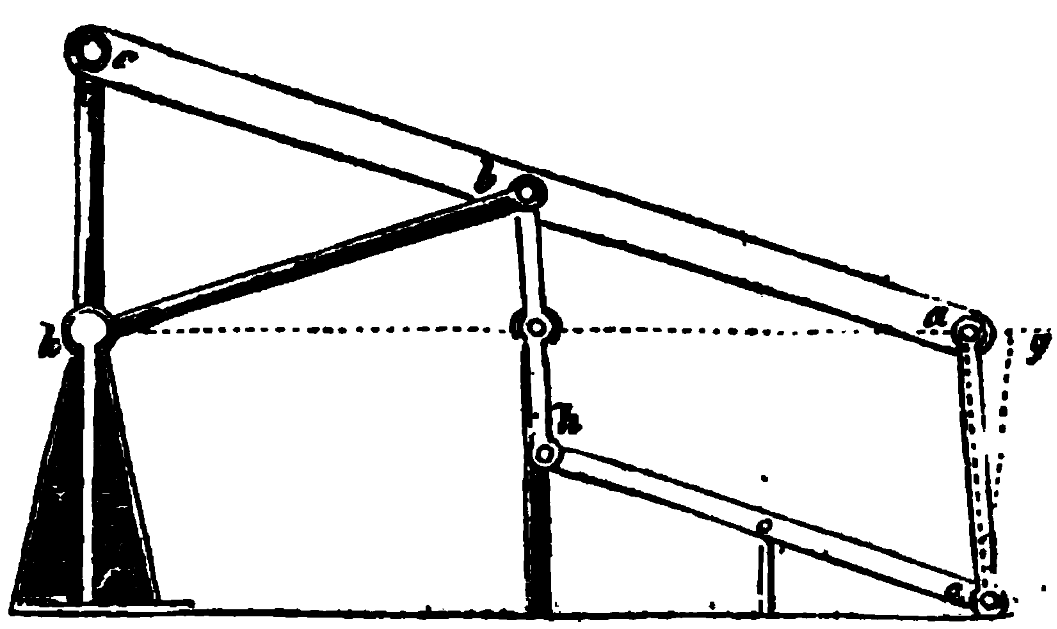
To find the length and centre of motion of the radius bar, with any distance in the compasses, and on the points $h\ m\ n$, describe arcs intersecting each other; and through the points of intersection draw lines cutting in o; then $o\ n$ will be the length of the radius bar, and o its centre of motion.

The Steam-boat Engine Parallel Motion in general use is represented by the annexed cut. The length of the radius bar, and the centre of motion, may easily be found,

as in the former case, by supposing the piston rod to move in a right line, and finding three points, through which a point in the side rod (assumed at pleasure,) would pass in the highest, lowest, and middle position of the piston rod; then a circle, which passes through these points, will give the radius and centre sought, and the point assumed in the side bar will be the point for its connexion with the radius bar.

a b c part of the beam, *c g* and *b h* side rods, *g* the point of junction of the piston to the side rod *c g*, and *m o* the radius bar.

In portable engines without a beam, the cross on the head of the piston rod has usually on its ends friction wheels running between guides, but we prefer the parallel motion introduced in Lloyd's portable engine, described hereafter, as it affords a convenient method of working the air-pump and cold-water pump. The principle of the parallel motion in this engine will be understood by reference to the following diagram.



a b c represent a bar corresponding to half the beam of an engine; *c k f* the path of the piston rod, and *b k* the radius rod: now the radius rod, and the two portions of the beam *a b* and *b c*, being respectively equal, if *a* move in a right line towards *g*, *c* will move in the line *c k*, and if *a* be connected to a rocking bar *a e*, which from its length, or its small angular motion, describes an arc *g a*, differing but little from a right line; and a side-bar or

strap *b h*, and the parallel bar *h e* being added, the centre of *b h*, will be the point of suspension for the rod of the air-pump, and the rod of the cold-water pump may be suspended from the parallel bar *h e*.

Condenser.—The condenser is a close vessel surrounded by water, and communicating with the cylinder by the eduction pipe. A small pipe rises a little way in the condenser, and is terminated by a nozzle pierced full of small holes. The water from the cistern in which the condenser is placed, flows through this pipe, and forms a jet within the condenser, and thus exposes a large surface of cold fluid to the steam entering from the cylinder, the greater part of which is thereby instantly reduced to water, and a partial vacuum formed at the same time in the cylinder. The greater the quantity of the injection water, and the lower its temperature, the more perfect will be the vacuum, and the power of the engine will be proportionably increased; but the most eligible quantity of injection water will depend upon the facility with which it may be procured, as more power might be expended in raising a large quantity, than the improved vacuum would compensate for. If the condensation of the steam should raise the condensing water to 120° Fahrenheit, the pressure of the condensed steam and air in the condenser will be equal to 3.7 inches of mercury; and the steam in the boiler being at the temperature of 220° Fahrenheit, and the water in the cold water cistern at 56°, the injection water required will amount to $\frac{1}{31}$th part of the cubic contents of the cylinder at each stroke.

Air-Pump.—In the conversion of water into steam, a quantity of air which had been previously combined with it is liberated, which, on the condensation of the steam, remains a permanent gas; if this gas were allowed to accumulate, its pressure would soon stop the engine. A pump, therefore, becomes a necessary appendage, to exhaust the air as fast as it is liberated by the steam; the action of which disengages a further portion of air from the injection water, which water must likewise be withdrawn from the condenser; and as the air-pump only

exhausts on the rising stroke of the engine, it must be of sufficient size to draw off all the air given out at two strokes of the engine, and the water required for condensation. This will require the air-pump to be about ⅛th of the capacity of the steam cylinder, or half the diameter and half the length of the cylinder.

The condenser was the first of Watt's grand improvements on the steam engine; by means of it, the cylinder is maintained at nearly the temperature of the steam, and a more perfect and speedy condensation is effected; but all these advantages are obtained simply by the steam being condensed out of the cylinder. Some engineers are of opinion, that an intermediate vessel between the cylinder and air-pump renders a larger air-pump necessary, (See Mr. Bramah's letter to Chief Justice Eyre, page 93). Mr. Tredgold says, that if the steam could be condensed in the body of the air-pump, a pump of half the capacity would be sufficient, and he gives a drawing of a *single-acting engine* without a condenser; but a double-acting engine would, in our opinion, require two air-pumps, or at least a double-action pump, to equalise the condensation at each stroke.

On account of the power necessary to work the air-pump, it has many times been purposed to effect the condensation of the steam, not by contact with cold water, but by exposing it to a large surface of metal immersed in water; and if by this means a sufficiently rapid condensation could be effected, the air-pump would only be necessary for a few strokes at starting the engine, and might afterwards be detached from the beam.

Mr. Cartwright, in 1794, took out a patent for an engine, in which the steam was condensed on this principle (see page 74), and an engine of this kind was constructed, and it is said to have given great satisfaction to the proprietors; but from its not having been adopted generally, we are inclined to doubt the truth of the statement.

Mr. Brunel likewise had a patent, in 1822, for the same object; his condenser consisted of several clusters of small

tubes surrounded by cold water. This invention was intended chiefly for engines for steam vessels, and certainly, in no case is it more desirable to condense the steam without bringing it in contact with the cooling fluid; as, by this means, steam vessels might use fresh water instead of sea water in the boilers, which would be productive of great economy, both in respect to the consumption of fuel and the greater durability of the boilers, which are rapidly destroyed by the salt water. We are not aware that the plan has been tried on board of any vessel, but, from the facility with which the water for condensation can be procured, we are disposed to think that success is attainable.

The size of the pump for supplying the injection water must depend on the facility with which the water can be procured. To condense the steam to the temperature of 120° Fahrenheit, will require about 20 times the quantity of water of which the steam is formed, or $\frac{1}{85}$th part of the cubic contents of the cylinder; and as the pump makes but one stroke to a double stroke of the piston, its capacity should be equal to $\frac{1}{42}$d part of the cylinder.

The injection water, having its temperature considerably raised by the condensed steam, is pumped into the hot well by the air-pump, and from this well the boiler is supplied with the water that is requisite by the hot-water pump. This pump must furnish, at each stroke, as much water as is requisite for steam, during a double stroke of the piston, besides an allowance for loss by the valves, leakage, &c. As steam occupies about 1700 times its bulk of water, the hot-water pump should furnish $\frac{2}{1700}$th parts of the contents of the cylinder, or, allowing for waste, should be $\frac{1}{1700}$th of the capacity of the cylinder.

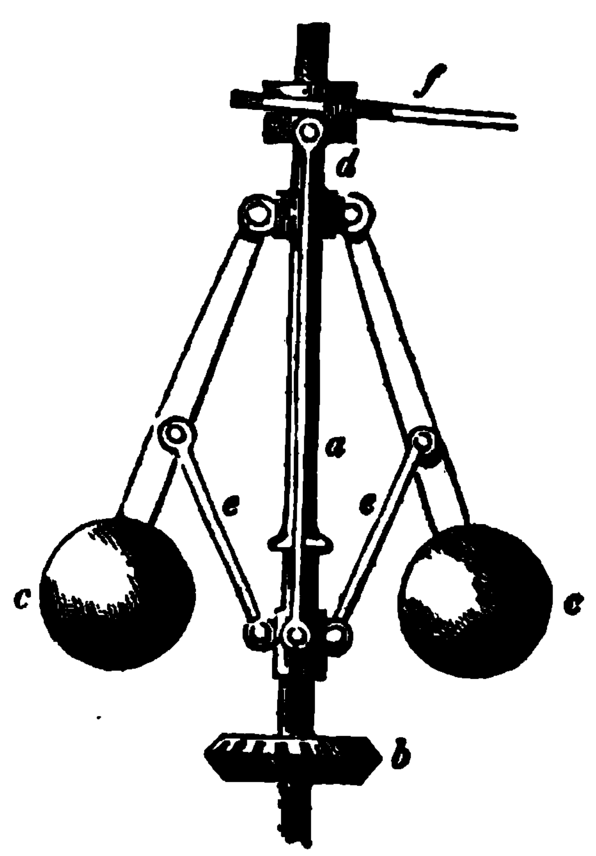
Supply of Water to the Boiler.—The manner of regulating the supply of water to the boiler is given in the chapter upon boilers, where a variety of methods are explained.

Safety Valves being an appendage to the boiler, are also described under the head of boilers.

Governor.—It has already been mentioned, in our de-

scription of the throttle valve, that, in order that the engine may in a certain degree be a self-regulating machine, the throttle valve is usually regulated by "a governor," connected with the fly-wheel. When the supply of steam exceeds in quantity that requisite for the work, the increased velocity of the fly-wheel causes the governor partially to close the throttle valve, and thereby diminish the supply of steam to the cylinder.

The arrangement of the parts of a governor may be a good deal varied, but the principle is the same in all, *viz.* the increasing or decreasing of the centrifugal force of two heavy balls, which, being set in motion by the revolution of the fly-wheel, operate, through the medium of a lever, upon the throttle valve. The annexed figure represents a governor used in an engine of Fentom, Murray and Wood, of Leeds.



a is an upright spindle revolving in a step, and set in motion by the fly-wheel acting on the bevelled wheel *b*, through an intermediate train of wheels; *c c* are two heavy balls suspended by jointed arms to the upright spindle at *d*; *e e* are two short bars, connecting the arms to a collar, which slides upon the lower end of the spindle; to this collar are jointed two vertical rods (one only can be seen), which support another sliding collar at the

upper end of the upright spindle, above the point of suspension *d*. In the upper collar is turned a groove, which receives a forked lever *f*, that is connected by other levers to the throttle valve. As the velocity of the fly-wheel increases, the centrifugal force causes the balls to revolve further apart; in doing this, their elevation is increased, which raises the lower collar, and the lower collar by its vertical rod raises the upper collar, which, by means of the lever *f*, acts upon the throttle valve, as beforementioned.

Field's regulating Valve is a contrivance introduced by Mr. Joshua Field, (of the firm of Maudslay and Co.); its object is to regulate the supply of the steam to the cylinder, in a superior manner to the throttle valve. We have never seen this invention applied, but Mr. Tredgold says that "it consists of a valve placed in the situation usually assigned to the throttle valve, that is, near to the place where the steam is admitted to the cylinder. This valve is to be opened at once, at the commencement of the stroke, so as to afford full passage to the steam, and shut at once, after a certain part of the stroke is made, that the rest of it may be completed by the power of the steam. This may be done by causing the valve to open by a tooth, or cam, on a cylinder, on one of the revolving shafts formed to raise the valve, and keep it open till the shaft has made part of its revolution, and then shut it. If the toothed cylinder be made to slide on the shaft, and the form of the tooth be such, that as the cylinder is moved in one direction the valve will shut sooner, and in the other direction later, there is then the means of regulating the power of the engine. This may be done either by hand, or by causing the cylinder having the tooth to slide by the governor."

Perkins's regulating Valve,—For cutting off the steam at any part of the stroke, is described hereafter, with the account of his expansive engine.

Fly-wheel.—The principles of the fly-wheel have already been so fully explained (at pages 65 to 69,) that we shall here give only the following simple rule for ascertaining the weight, extracted from Brunton's Compendium.

Multiply the number of horses power of the engine by 2000, and divide by the square of the velocity in feet, of the circumference of the wheel per second, and the quotient will be the weight in cwts.

Example:—Required the weight of a fly-wheel, proper for an engine, at 20 horses power, the circumference of the wheel moving at the rate of 1232 feet per minute.

Velocity, 1232 per minute;

$20\frac{1}{2}$ per second, 20 horses
$20\frac{1}{2}$ 2000

Square $420\frac{1}{4}$)40000(90.4 cwt. weight of wheel.

As the most disastrous consequences might result from the breaking of such a heavy mass as the fly-wheel, when moving with great velocity, and several fatal accidents having actually occurred, we think that for all engines, above 10 horses power, the fly-wheel ought to be composed entirely of wrought-iron, its force to resist tension being so much superior to cast-iron.

Calculating the power of Engines.—Having described in detail the principal constituents of the steam engine, we shall proceed to give the rules for calculating the power from its dimensions, and for determining the dimensions proper for an engine of a desired power. These rules we shall select principally from Mr. Tredgold's excellent treatise on the Steam Engine, referring such of our readers as are desirous of examining the foundations of the rules to the work itself, in which they will find a minute and philosophical investigation of the effect of every circumstance by which the power of the engine is affected. The first point to be ascertained is the amount of the *effective pressure* upon the piston. The whole force of the steam in the boiler, is not effective in raising the load, various deductions being necessary for loss by condensation,-leakage, friction, &c. The loss from these causes, in an engine having no condenser, is estimated as follows:

The pressure on the boiler being		10.000
1. The force necessary for producing motion of the steam in the cylinder	·0069	
2. By cooling in the cylinder and pipes	·0160	
3. Friction of piston and waste	·2000	
4. The force required to expel the steam into the atmosphere	·0069	
5. The force expended in opening the valves, and friction of the parts of an engine............	·0622	
6. By the steam being cut off before the end of the stroke	1000	
Amount of deductions		3920
Effective pressure....		6080

nearly $\frac{6}{10}$ths of the whole pressure of the steam in the boiler; and if we deduct, from the remaining $\frac{6}{10}$ths, the amount of the pressure of the atmosphere, the result will be the effective pressure, when the engine is not working by expansion.

Example.—If the pressure in the boiler be equal to 120 inches of mercury, and the pressure of the atmosphere 30 inches, the effective pressure will be $\frac{6}{10}$ths of 120=72 less 30=42 inches.

In a condensing engine the loss is estimated as follows:—

The pressure on the boiler being		1000
1. By the force required to produce motion of the steam into the cylinder..............................	007	
2. By the cooling in the cylinder and pipes..........	016	
3. By the friction of the piston and loss	125	
4. By the force required to expel the steam through the passages	007	
5. By the force required to open and close the valves, raise the injection water, and overcome the friction of the axes	063	
6. By the steam being cut off before the end of the stroke	100	
7. By the power required to work the air-pump......	050	
		368
		632

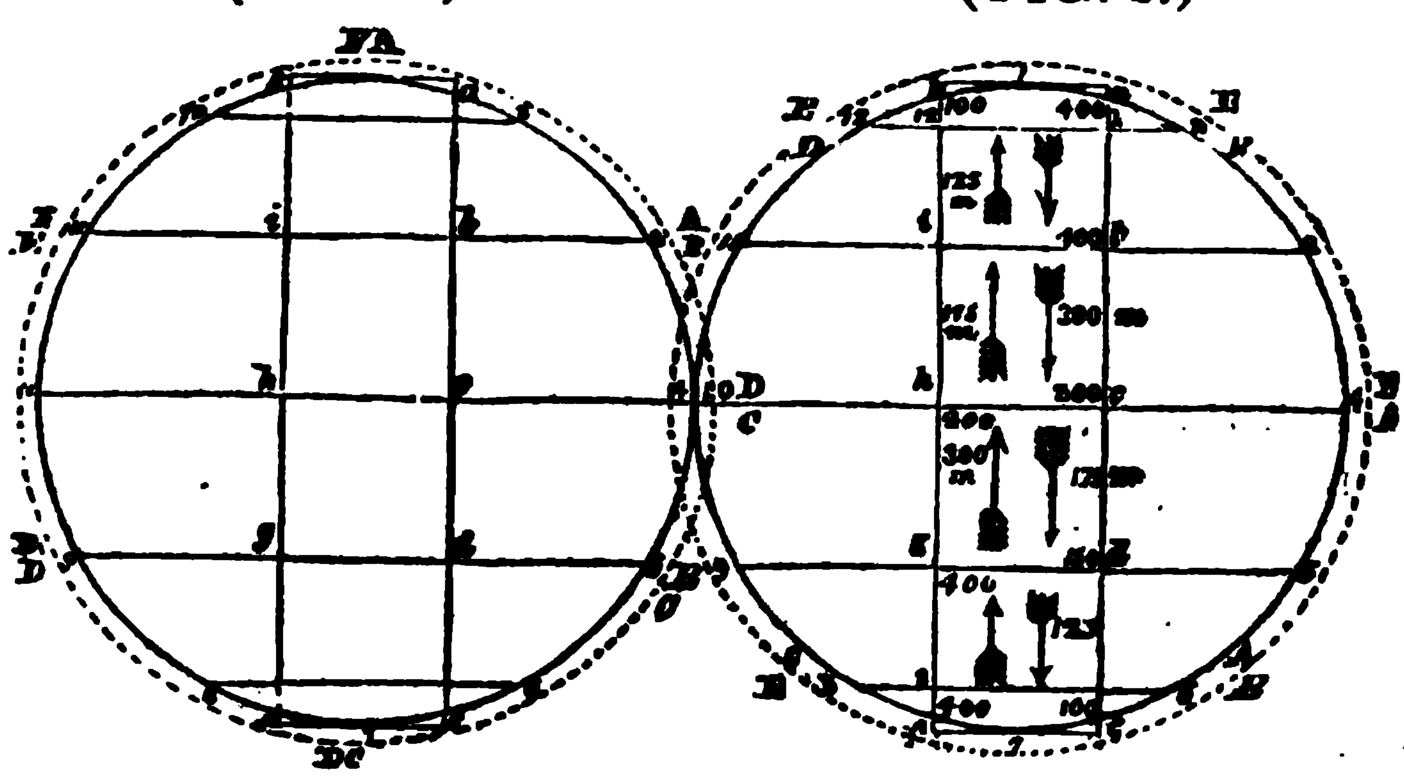
The pressure of steam on the boiler is generally 35 inches of mercury, for condensing engines, and the pressure of the uncondensed steam is 3.7 inches; the difference between the two pressures is 31.3 inches, which, multiplied by 632, gives 18.42 inches=7.1 lbs. circular inch, as the

effective pressure upon the piston, when the engine does not work expansively.

Working by expansion.—But it is found advantageous to work by the expansion of the steam; that is, to cut off the steam at a given portion of the stroke, and allow the remainder of the stroke to be effected by the expansion of the steam; by which means, all the power obtained by the expansion of the steam is gained, and this, in high-pressure engines, is considerable. The following popular illustration of this subject, by Mr. Perkins, is extracted from the Register of Arts, and Journal of Patent Inventions, (vol. i. N. S. page 72.)

"The diagram, figs. 1 and 2, will shew the economy of using steam expansively, and also the method of compensating for the inequality of the pressure on the piston, which if steam of 400 lbs. to the square inch be used, and stopped off at the quarter stroke, will end its stroke at 100 lbs. per inch. The diagram will also show that the motion of the piston is constantly varying, while that of the crank is uniform in its motion.*

(FIG. 1.) (FIG. 2.)



* This diagram does not pretend to mathematical accuracy; the object is merely to explain to the practical mechanic, in a sufficiently clear and concise manner, the principle of the advantage gained by using steam expansively.

Fig. 1. AA 400	Fig. 1. BB 475	Fig. 1. CC 125
2. AA 275	2. BB 125	2. CC 600
675	600	725
Fig. 1. DD 400	Fig. 1. EE. 475	Fig. 1. FF. 125
2. DD 275	EE. 125	FF. 600
675	600	725

"From repeated experiments, and much reflection, I am led to believe that there is great economy in using very high steam, and that expansively; that the higher you can practically use the steam, the sooner you may cut it off. The diagram shews the gain in cutting off the steam at the quarter stroke. Let the piston, which is represented by the line *k*, 1 *a*, descend to *i b*, being one quarter of the stroke, with a constant pressure of 400 lbs. per square inch. At this point let the steam be cut off, and expand to double its volume; when it arrives at *h c*, it will be exerting a pressure of 200 lbs. per inch, producing a mean of 300 lbs. per inch, through the quarter stroke. Let the steam again expand to double its volume, and the piston will finish its stroke at *f e*, at 100 lbs. per inch, giving a mean of 150 pounds per inch for each quarter, which add to the other two quarters, 400, 300, 150, 150, and the whole sum will be 1000,* giving an average pressure of 250, per square inch. It will be seen that, when the stroke is completed, the cylinder will be filled with steam at a pressure of 100 lbs. per inch, which will be the same in quantity as though the steam had begun with a pressure of 100 lbs. per inch, and continued all the stroke at that pressure. By using the same quantity of steam expansively, beginning at 400 lbs. there is a gain of 150 per cent. If the steam be used at 600 lbs. per inch, and cut off at one-eighth of the

* If the steam had continued the whole length of the stroke at 400 lbs. per square inch, the sum would have been 1600 lbs.; consuming four times the steam, with the addition of only 60 per cent to the power.

stroke, 225 per cent. will be the gain. To compensate for the unequal pressure of the steam upon the piston, two cylinders should be used, particularly for steam boats and pumping, where the fly should be dispensed with. With the following arrangement, it will be seen, while one of the pistons is at its greatest power, the other is acting with a diminished power.

"The piston 1, fig. 1, in descending from *a* to *b*, moves, in the same time, through half the space through which the crank moves, as will be seen by its path from 1 to 3. A force of 400 lbs. is exerted on the square inch, (that being the pressure of the steam,) in the first quarter of the stroke; at this point the steam is cut off, leaving the other three-fourths of the stroke to act expansively. The piston 1, fig. 2, having completed half its stroke, when piston 1, fig. 1, begins its stroke, and consequently a compensation near enough for all practical purposes takes place.

"It will be seen, that while the piston 1, fig. 1, has performed one-fourth its stroke, that the piston 1, fig. 2, has moved from *c* to 6, performing seven-sixteenths of its stroke in the same time. The mean in each quarter, from *c* to *e*, fig. 2, being 150 lbs. the amount of pressure to be added to the first quarter of the stroke of the piston, fig. 1, (which was 400 lbs.) is 275 lbs., producing an available power of 675 lbs. at this part of the stroke. The piston, fig. 2, now moves but two-sixteenths of its stroke from 6 to *e*, and *f* to 8, while the crank moves through two of its divisions, from 6 to 8, which would, in another part of its path, move (within a fraction) with the same velocity as the piston. The piston, fig. 2, in moving from 6 to *e*, gives a power of 25 lbs. being the last of the expansion which ends at 100 lbs. per inch. The piston, fig. 2, in moving from *f* to 8, being the beginning of the stroke, gives a power of 100 lbs.; thus a power of 125 lbs. will be acting in the piston 1, fig. 1, while moving from *b* to *d*, giving a power of 475 lbs., to which add 125, will shew a power of 600 lbs. at this part of the stroke. The piston 1, fig. 1, now descends from *d* to *e*, being the last quarter of the stroke, giving 125 lbs. of power to act with the piston 1, fig. 2, while moving from

8 to *h*, giving a power of 600 lbs.; add to this the 125 lbs. and it will give a power of 725 lbs. at this part of the stroke. The piston 1, fig. 1, now begins its stroke of 400 lbs. per inch at *f*, and continues to *g*, with the same power, while piston 1, fig. 2, moves from *h* to 12, giving a power of 300 lbs. to be added to the 400 lbs. obtained at the first quarter of the stroke of the piston 1, fig. 1, at *f* and *g*, producing at this part of the stroke 700 lbs. of power. The piston 1, fig. 1, now moves from *g* to *i*, giving a power of 475, while the piston 1, fig. 2, moves from 12 to *k*, and *a* to 2, giving a power of 125; which added to 475, gives a power of 600, at this part of the stroke. The piston 1, fig. 1, now moves from *i* to 1, being the last quarter of the stroke, giving a power of 125 lbs., while the piston, fig. 2, moves from 2 to c, producing a power of 600, to which add 125 lbs., will make 725 lbs. at this part of the stroke.

"By this arrangement it will be seen, that a compensation is obtained, giving a more equable power than that which is produced by the single engine, whether high or low pressure, since it is well known that at two points of the revolution of the crank, the power ceases, during at least one-sixth of the time, which is the reason that so large a fly-wheel is necessary. It is particularly applicable to steam-boats, and may be used to great advantage in the double pump, as well as the balance-bob lifting pump, used in Cornwall for mining purposes, by the use of proper gearing. The present single stroke expansive engines, used in Cornwall for pumping, are preferred to all others on account of their economy, although they are very limited, as to the extent of the expansive principle, for want of compensation, as nearly the same power is wanted to finish the stroke of the pump as to begin it.

"The variation of the velocity of the piston, occasioned by the compound motion of the crank and connecting rod, is not taken into view in this diagram. As the connecting rod is intended to be four diameters of the path of the crank, the variation will make no practical objection, being, at its greatest value, but one thirty-second part of its

range. If the engine should be worked by a connecting rod, as is sometimes the case in steam boats, say only one diameter of the path of the crank, the variation at each end of the stroke would amount to a practical defect, since the piston would move with nearly three times the velocity at the lowest quarter of the stroke, that it would at the first quarter. Thus circumstanced, the crank must be above the cylinder.

"As the law of expansion seems not yet to be settled, an arithmetical expansion has been used for this diagram, which, from its approximation to the real law, will be quite near enough for practical purposes. Many who are of the school of Tilloch and Woolf, believe that the expansive power of steam depends upon heat only, while the Soho experiments are said to prove that elasticity depends simply on density, without regarding temperature, *viz.* that if a cubic foot of steam at atmospheric pressure weighs one ounce, fifty atmospheres of steam would weigh fifty ounces; but Dalton, who is undoubtedly much nearer the true law, would make fifty atmospheres weigh but about thirty-four ounces.

"I have no doubt that the nearer the atoms of water are made to approach each other by compression, the greater will be the repulsive action of caloric; and that in a more rapid ratio than has hitherto been allowed, especially in highly compressed steam. Its comparative density with the increase of power diminishes faster than has been supposed even by Dalton."

The advantages of allowing the steam to expand being so clear, we must next determine the best point for

Cutting off the Steam.—The pressure of the steam upon the piston should never be less than the resistance from the friction, &c. added to the pressure of the atmosphere in non-condensing engines, or the pressure of the uncondensed steam in condensing engines; and as the pressure of the steam is inversely as the space it occupies, if we divide the amount of the friction, &c. added to the pressure of the atmosphere, or of the uncondensed steam by the pressure of the steam in the boiler, the quotient will give the portion of

the stroke at which the steam should be cut off, to produce the greatest effect.

Example—The pressure in the boiler being 120 inches, the loss from friction, &c. is ·4 $\frac{4}{10}$=48, which added to 30 inches, the pressure of the atmosphere, is 78; and this divided by 120 gives ·$\frac{65}{100}$ as the part of the stroke at which the steam should be cut off.

The pressure of the steam upon the piston decreasing towards the close of the stroke, in order to compute the power, we must first ascertain the *mean* effective power which has been exerted throughout the whole stroke; for non-condensing engines, Mr. Tredgold gives the following rule.

Let the portion of the stroke at which the steam is cut off, be represented by a fraction whose numerator is 1; then multiply the logarithm of the denominator by 2.3, and add 1 to the product; then divide the sum by the denominator, and subtract 0.4 from the quotient, and the remainder being multiplied by the whole force of the steam in pounds per circular inch, and 11.55lbs. subtracted for the pressure of the atmosphere, will give the mean effective pressure on the piston, in pounds per circular inch.

Example.—Let the pressure in the boiler be 46lbs. per circular inch, and the steam cut off at ⅔ds of the stroke.

$\frac{2}{3}=\frac{1}{1.5}$ Logarithm of 1.5 × 2.3 = 0·405
1·
1.5) 1·405
·936
·4 Allowance for friction, &c.
·536
46 lbs. the pressure in the boiler.
24·656
11·55 resistance of atmosphere.
Mean effective pressure, 13·106 lbs. per circular inch.

But it is only by condensing the steam, after allowing it to expand, that the greatest possible effect is derived from

steam; in this case, the rule for finding the mean effective pressure is as follows:—

Let the part of the stroke at which the steam is cut off, be represented by a fraction whose numerator is 1; then multiply the logarithm of the denominator by 2·3, and divide the product by the denominator, and the product multiplied by the whole force of steam in the boiler in pounds per circular inch, will give the mean pressure.

Example—Let the pressure in the boiler be 35 inches, or 13.5lbs. per circular inch, and let the steam be cut off at $\frac{1}{2}$ of the stroke.

$\frac{1}{2}=\frac{1}{2\cdot1}$ logarithm $\cdot322219\times\frac{2\cdot3}{2\cdot1}=\cdot354\times13\cdot5=4\cdot8$ lbs. per circular inch.

The velocity with which the piston should move is shown by Mr. Tredgold to be ¼th of the velocity which a body would acquire in falling through the length of the stroke, which being eight times the square root of the length, gives twice the square root of the length of the stroke, as the velocity of the piston per second, or 120 times the square root per minute, suppose the steam to act on the piston during the whole stroke with the same pressure; but the imperfection of the valves not admitting of this, he gives the following rule for engines acting expansively.

Let the part of the stroke at which the steam is cut off, be represented by a fraction whose numerator is 1, multiply the logarithm of the denominator by 2·3, and add ·7 to the product; multiply the sum by the portion of the stroke at which the steam is cut off, and the square root of the product, multiplied by 120, gives the velocity in feet per minute.

Example.—Let the steam be cut off at ¼, and the stroke be eight feet long, required the velocity.

$$
\begin{array}{lr}
\frac{1}{4} \text{ log. is} & 0\cdot60206 \\
 & 2\cdot3 \\
\hline
 & 1\cdot38473 \\
 & +\cdot7 \\
\hline
 & 2\cdot08473 \\
\frac{1}{4} \text{ of } 8= & 2 \\
\hline
\end{array}
$$

$4\cdot169\surd\times120=245$ feet per minute.

In engines not intended to work expansively, the steam may be reckoned as cut off at ¼ of the stroke, and then 103, the square root of the length of the stroke = to the velocity.

Example.—The steam acting under full pressure, and the length of stroke eight feet, required the velocity.

8 √	log. 0·45154
103	2·01283
291 velo. =	2·46437

To find the Power of an Engine.—Multiply the square of the diameter in inches by the effective pressure in pounds per circular inch, and the product by the velocity in feet per minute, and this product will be the number of pounds raised one foot high per minute, which, divided by 33,000, will be the number of horses to which the engine is equivalent.

Example.—Required the power of an engine, the diameter of the piston being two feet, length of stroke four feet, and effective pressure per circular inch 7·1 lbs.

Diameter, 24 inches square =	576
Effective pressure..........	7·1
	4089·6
Velocity	203
Pounds raised one foot high..	842457·6

And 842457 ÷ 33,000 = 25½ horses.

To ascertain the dimensions of an engine of a given power, to work at a given pressure, and the diameter to be in any proportion to the length:—

Let the proportion between the diameter and length of the stroke be represented by a fraction whose numerator is 1, divide 12 by the denominator, and find the logarithm of the √ of the quotient, and to this add the logarithm of 33,000, and from the sum subtract the logarithm of the effective pressure, and the logarithm of the number, which multiplied into the square root of the length, would give the velocity; the remainder multiplied by 2, and divided

by 5, will give the diameter in inches, from whence the length of stroke and velocity may be found.

Example.—Required the diameter of the cylinder for an engine of 30 horse power, with the length of the stroke, and velocity per minute, the length of the stroke being twice the diameter of the piston, and the effective pressure 7.1 lbs. per circular inch, to work at full pressure. At full pressure, the square root of the length, multiplied by 103, gives the velocity per minute.

Proportion of diameter to stroke ½ and 12½ 2=6 log.	0.77815	0.38907
33000 .... log.	4.51851	4.51851
30 horses.............. log.	1.47712	1.47712
Sum......	6.77378	6.38470
7.1 eff. pressure log. 0.85125		
103............log. 2.01283		
	2.86408	2.86408
	3.90970	3.52062
	2	2
	5)7.81940	5)7.04124
Inches diameter 25.........	1.56388	1.40825

SECTION IV.

STEAM-BOAT PROPELLING MACHINERY.

A STRONGER proof of the importance attached to this subject cannot well be afforded, than by the curious fact, that no less than seventy different inventions have recently been patented, for the propulsion of steam vessels. It is hardly possible to suppose that the exertion of so much mechanical ingenuity can fail to effect some improvement upon the ordinary paddle-wheels, which are universally admitted to possess many great and glaring defects; nevertheless, it is a remarkable circumstance, that among the very

numerous attempts to obviate these defects, consisting of new modifications of the wheel, as well as substitutes for it, very few have been purposed, that have not been calculated either to augment the evils, or to introduce others of greater magnitude. In the latter part of Mr. Galloway's work in this volume, he has introduced a short treatise on this subject, to which the following account of new contrivances for propelling, chronologically arranged, will form a valuable addendum.

(FIG. 1.)

(FIG. 3.)

Patent Paddle-wheel Cases, by Mr. D. Gordon, of the London Portable Gas Works. 1822.

The patentee purposes to enclose the ordinary paddle-wheels in a *case*, in such a manner that the edges of the paddles of the wheel have only just liberty to move freely between the sides of the case; in front (*i. e.* towards the bow of the vessel,) the water enters at an aperture in the

case, entirely below the level of the water line, which, having been operated upon by the paddle-wheels, escapes freely at the back, the case being left quite open in that part for the purpose. By this method of inclosing the paddle-wheels, it is considered that they will act with much more effect, and propel a vessel faster, as the water cannot escape either sideways or downwards, but is forced to enter the aperture, and be fairly driven out behind. Another advantage derived by this casing, of no less importance, is the protection it affords the paddle-wheels from the violence of the waves, which not unfrequently causes serious damages and accidents, when left exposed in the usual way.

The diagram fig. 1, is intended to exhibit a side view of a vessel so constructed; and fig. 2, is a view towards the head of the vessel; the same letters referring to similar parts in each of the figures.

a is the paddle-wheel case, the wheel within being represented by dotted lines; *b* is the fore part of the keel, under the bows of the vessel; *c* is the aperture for the water to enter, and *d* the open back part of the case, for the water to escape; the dotted line *e*, shows the level of the water line, above the apertures *c c*, beforementioned.

The specification describes several differently formed vessels, both for inland and sea navigation, and shows, by reference to accompanying plans and sections, that the invention is equally applicable to them all, and in whatever part of the hull the paddle-wheels or *wheel* may be situated. The construction of steam vessels with only one paddle-wheel placed at the stern, and in the middle of its breadth, though not entirely new, (nor claimed under this patent,) is too remarkable for us to pass over; we have, therefore, selected the third figure in our engraving, to represent the patentee's method of applying his invention to vessels of this kind. The figure gives a longitudinal section of a steam-boat more especially adapted for inland navigation. This vessel is intended to have a channel or course made through its whole length along the bottom, being open at the under side, (like an inverted trough,)

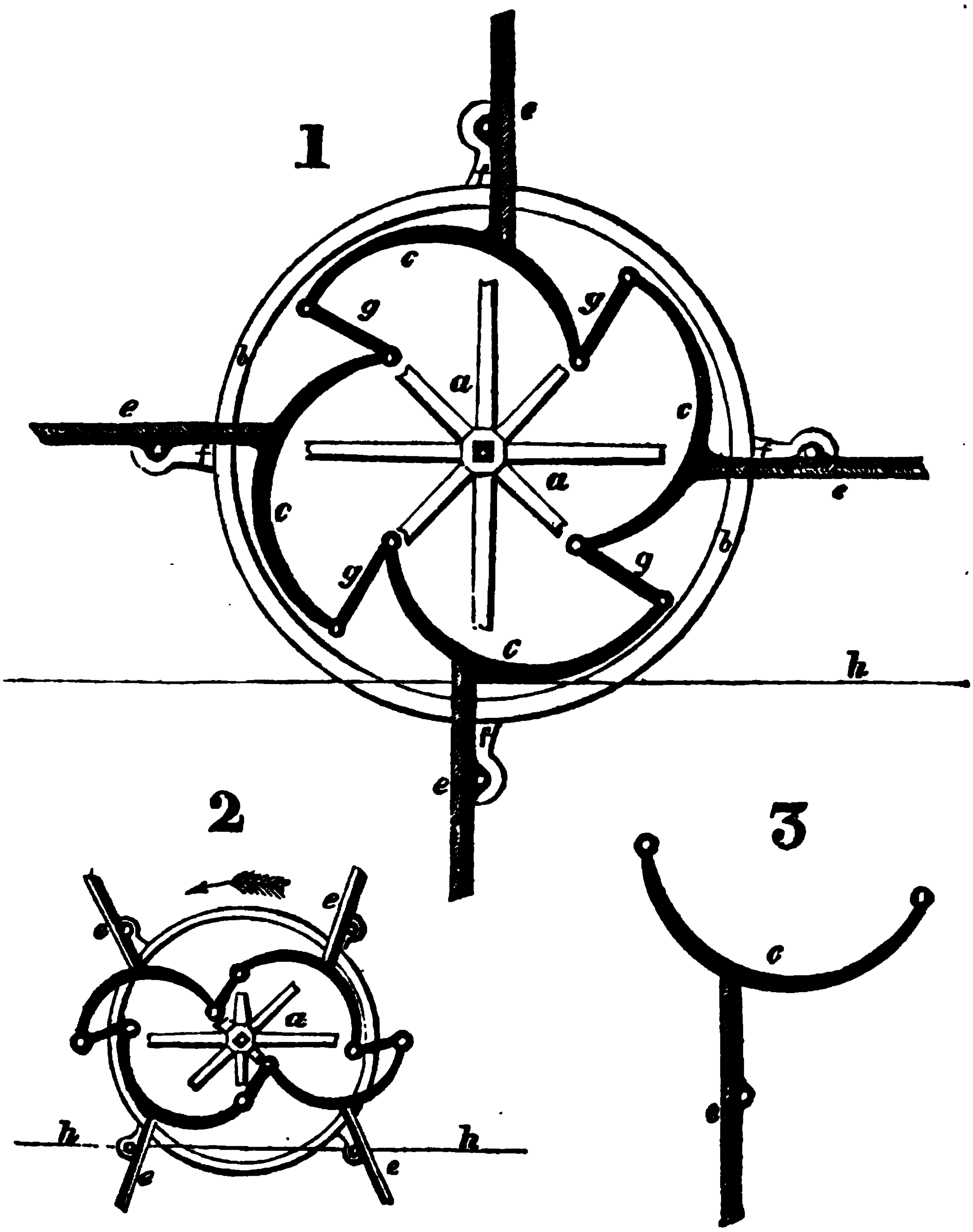
until it comes to the part where the paddle-wheel case commences; and there the channel is closed up under the paddles, so as nearly to touch their extremities as they revolve. It is likewise intended that this vessel shall be steered by two rudders, placed one on each side of the paddle-wheel, and connected together by jointed rods, so as to be moved by one lever or tiller. The paddle-wheel, in its case, is shown at *a*; the aperture for the entrance of the water at the end of the long channel at *c*, which escapes freely at the back, as the rudders, being placed at the sides of the stern, offer no obstruction.

The aperture for admitting the water to the paddle-wheel, the patentee recommends to be furnished with a sluice or gutter, so that the water may be supplied in greater or less quantity, by increasing or diminishing the aperture, according to the velocity of the wheel, or to the roughness of the water in which the vessel is navigated. It is also recommended that the said aperture shall be protected by flat bars of metal placed edgeways, so as to form an upright grating, to prevent any floating substances from driving against the paddle-wheels, and at the same time not to prevent the free entrance of the water.

Patent Steam Boat Paddles, by Lieut. W. H. Hill, of Woolwich. 1825.

The object of this invention is to give a more efficient direction to the paddles, by causing them to describe an elliptical curve in passing through the water; to descend into it at an angle nearly perpendicular to its surface, and ascend out of it at a similar angle; by these means to obtain all the advantages of the resistance of the water as a fulcrum to the leverage of the paddles, and avoid the opposing disadvantages incident to the ordinary paddles at their entrance into and exit from the water. The arrangement is no less singular than ingenious.

a a a, fig. 1, represent the spokes of the paddle-wheel, shown as disconnected and broken off from the periphery *b b*, to prevent its being confused with the novel propel-



ling part; *c c c c* are four bent levers, one of which is shown separately by fig. 3; *e e e e* represent the edges of the paddle-boards, which are bolted to the straight arms of the levers c, and are connected by axles to four short arms *f f f f*, which radiate from the periphery of the wheel; each end of the curved part of the levers is attached to the next lever in the series, by an intermediate short rod *g g g g*. Owing to this mode of connecting the short rods by pivot joints, the resistance of the water

against each immersed paddle, causes the next in succession which is entering the water, to be depressed at its extremity, thereby throwing it into that position, or that angle with the surface of the water, by which it meets with the least impediment to its immersion. The resistance of the water upon the paddle that has preceded it, then draws the other into the vertical position, at the same time that it is itself being raised out of the water, at a similar angle to that by which it entered; these motions are communicated successively to all the paddles by the revolution of the wheel, which will be understood by an examination of fig. 2, wherein are represented the positions into which the paddles and levers are thrown, by the exit and entrance of the paddles.

In the Repertory of Patent Inventions, No. 7, the whole of the specification of Mr. Hill's patent is inserted, which contains geometrical instructions for the formation of this ingenious apparatus, so as to insure the true and uniform action of the parts.

Patent Propelling Machinery, by G. H. Palmer, of the Royal Mint. 1826.

This invention is so simple, both in its construction and application, as to need no explanatory engravings. It consists of chains passing horizontally along the sides of a vessel, or along the bottom between false keels, with paddles jointed to a guide frame, to which they are attached in such a manner, that when the chain is drawn in a direction from stem to stern, the paddles will be kept in a perpendicular position by small check chains, proceeding from the lower extremity of the paddle, to the main chain or guide frame, in an angular position; thus forming a resistance to the water, which propels the vessel forwards, as the chains with the paddles are dragged backwards. When the horizontal parts of the chains are returned, or moved from stern to stem, the paddles fold up and take a horizontal position with the chains, and therefore form no resistance in passing through the water. The chains are

kept in their places by passing over guide pulleys at each end of the horizontal or lower ports, and over wheels at the upper ports. The wheels are furnished with spikes on their peripheries, which take into the links of the chains. These wheels are put in motion by a band passing over a drum in connexion with a steam engine, and round a small rigger attached to the axis of each of the spiked wheels.

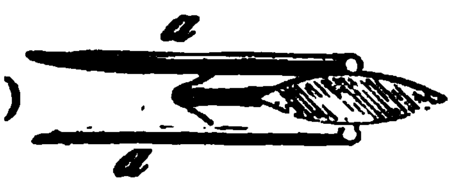
When the paddles have been made to traverse their assigned distance along the vessel, in the direction from stem to stern, they are returned to their first position by reversing the motion of the spiked wheels.

If the paddles be used on the sides of the vessel, the spiked wheels and guide pulleys are attached to triangular frames, which are firmly fixed to the sides. But if they be applied to the bottom of the vessel, (which the patentee recommends when they are used for barges on canals, as they will in that case agitate the water less, and consequently do less injury to the banks of the canal,) they must be placed between false keels. In this case the same spiked wheel will serve to give motion to both chains at the same time, by passing them round it in contrary directions; hence one paddle or set of paddles will be kept in action, while the other is returned through the water in a horizontal position.

Patent Propelling Machinery, by John Nairn, of Edinburgh. 1828.

Two, four, or more levers are to be suspended over the sides of a vessel, and to descend nearly as low as the vessel's keel. These levers are to be moved backwards and forwards, like a pendulum, the motion being communicated by a steam engine, or other prime mover; and that the levers may experience but little resistance from the water, they should be of such a shape as to present in their horizontal section a form like the adjoining fig. 1.

(FIG. 1.) 

(FIG. 2.) 

At each side of the lever, at its lower extremity, is attached a broad plate of iron, *a a*, fig. 2, by means of hinge joints, which, upon the lever being moved forward, close, and offer no resistance; but when it is moved backward, they open or expand, and thereby impel the vessel forward. To prevent their opening beyond the proper angle, which is from 140 to 160 degrees, a circular arc may pass through them, or they may be connected to chains, which only allow them a certain range of opening, or any other method to admit their expansion within due limits.

There have been many previous contrivances for propelling, bearing a resemblance to Mr. Nairn's invention, which have failed in practice; and we can discover nothing in the present contrivance calculated to render it an exception.

Patent Propelling Machinery, by Paul Steenstrup, of Basing Lane, London. 1828.

In the ordinary construction of paddle-wheels, it will be observed that each paddle is fixed in the direction of radii, and it is equally obvious that some power must be lost in depressing the paddles, in their descent into the water, and likewise in raising them out of the water in their ascent, when they have to lift a portion of water, called the tail-water. In most of the attempts to remedy this defect, the inventors have caused the paddles to maintain a perpendicular position, throughout the revolution of the wheel; and very different opinions have been recently entertained, with respect to the angle at which they ought to enter the water. Mr. Steenstrup considers that the paddles entering the water should have a certain obliquity, varying as the paddle advances in its revolution. He ob-

(FIG. 1.)

(FIG. 2.)

serves, that as every part of the periphery of the wheel must describe a cycloid, the paddles should at every part of their revolution form tangents to that curve; accordingly he has purposed four very simple and ingenious modes of effecting this movement.

Fig. 1. in the preceding page, shews what he deems the simplest method; *a* represents the paddle-wheel, *b* a cog-wheel bolted to the vessel's side, concentric with *a*, and allowing the shaft *c* of the paddle-wheel to revolve in its centre; *d* a cog-wheel, double the diameter of *b*, revolving upon an axis supported by the arms of the paddle-wheel, and gearing into *b*; *e* the paddle, suspended by axles turning in the rim of the wheel; on each of these axles is fixed a chain wheel *f*, and a similar wheel is fixed on the axis of the cog-wheel *d*; *g* is an endless chain, passing *over* the wheels *f*, on the periphery of the paddle-wheel, and *under* the wheel *f*, on the axis of *d*; *h* represents a water line.

It will now be perceived that when the paddle-wheel is set in motion, the toothed wheel *b* being fixed, causes the large-toothed wheel *d*, to revolve upon its own centre, at the same time that it is carried round by the paddle-wheel, in a manner similar to the sun and planet wheel, in Watt's steam engine. The wheel *d*, being double the diameter of *b*, will perform one revolution upon its own axis, in the same time that it is carried round once by the paddle-wheel; and by means of the endless chain, passing under the small wheel *f*, on its axis, will cause each paddle to revolve once on its axis in the same time; and each paddle is constantly directed to the highest point in the rim of the wheel, which position of the paddles, by a diagram accompanying the specification, the patentee shews is nearly the required tangent.

Fig. 2. shews the other method; instead of the endless chain, a large-toothed wheel is placed loose on the axis of the paddle-wheel; this toothed wheel acts upon the wheels fixed on the axis of the paddles, and is put in motion by an endless chain *g*, passing over a small wheel *m*, placed on the axis of *d*, and over a similar wheel *n*, in the axle of one of the paddles. The other parts being similar to those in fig. 1, require no further explanation.

The patentee purposes in general, that these wheels should be immersed in the water about one-third of the diameter, which is considerably more than the wheels at present can be immersed; and thus the same number of paddles can be brought into action as in a wheel of larger dimensions; he indeed states, that the wheel will work well when totally immersed, and in any position, oblique, horizontal, or perpendicular.

From recent experiments on the Thames, the fact of these paddles working well when totally immersed, and in various positions, has been proved; and this property seems to confer upon them a decided advantage in the plunging of vessels in heavy seas. We fear, however, that notwithstanding the simplicity of the arrangement by which the paddles are made to change their position, the parts are too numerous, and should it happen that one link be broken (which is probable) "the whole chain is destroyed."

Patent Paddle-Wheels, by Lieutenant Skene, R.N. of Woolwich. 1828.

This invention is purposed by the patentee as an improvement upon the paddle-wheels of steam boats, and also of the common water-wheels employed in driving machinery on land. The form and full size of the paddles are a parallelogram, 1 foot deep, by 2 feet wide, terminated by a semicircle of 1 foot radius. These paddles are not immoveably fixed, but vibrate on axes passing through the two opposite annular plates that form the periphery of the wheel, in order to allow of their dipping into the water edgeways, and thereby reducing the resistance of the water to the revolution of the wheel. For this purpose, the lower or semi-circular portion of each paddle is loaded with metal, the superior gravity of which, to that of the upper portion, causes each paddle successively, as it enters the water, to assume the vertical position; and to prevent their turning over, a simple stop is provided (which will presently be explained,) so that the full effect of the impelling power of the engine may be given to each paddle, at the proper time. To prevent the water from escaping sideways between the arms of the wheel, a large disc or

(FIG. 1.)

(FIG. 2.)

circular plate is fixed against the internal sides of the wheel, and of such diameter as not to come within the range of the paddles, as they vibrate on their axes.

The number of paddles to each wheel is to be regulated by the diameter of the wheel; which is, for every foot in diameter, one paddle; therefore, for a six-foot wheel there are to be six paddles, which is the number represented in the opposite engravings. The patentee states that the *paddles* should never exceed two feet in breadth; but vessels that require a greater breadth of *wheel*, should have an additional rim attached to the axis of the wheel, within which the additional series of paddles are to be placed; but the axes of this series of paddles are not to be in the same horizontal lines as the axes of the others, but midway between each, in order that the paddles of each series may enter the water in alternate succession; because, by such arrangement, the motion will be rendered more equable.

Fig. 1. represents a side elevation of the wheel, with the paddles, consequently, viewed *edgeways;* and fig. 2, (annexed,) exhibits a single paddle, *flatways*, on a larger scale; the same letters of reference in each figure indicate similar parts.

a a a are the arms of the wheel, revolving upon the shaft *b*; *c* is the circular plate, to keep the water from passing laterally; *d d d* are the paddles, of which *f f f* are the loaded sides; *b b b*, are the axes of the paddles, the dotted arcs of circles, at the extremities of the paddles, shew the range of their motion, which is arrested by the stops *e*, that consist merely of a prolongation of the upper sides of the paddles striking against the arms, or the inside of the rims of the wheel. The arrows show the direction in which the wheel turns.*

* It is proper here to notice, that Mr. Skene considered his invention to be misrepresented by the above description, which is extracted from the second volume of the Register of Arts and Journal of Patent Inventions, page 196. In an account which appeared subsequently in the Mechanic's Magazine, communicated by the patentee, he states, that the wheel in propelling is made to revolve in the *contrary direction* to that which we have represented it. The reader is, therefore,

From the preceding account, the action of these wheels is too obvious to require any explanation. We understand that they have been applied to a steam boat on the Thames, and the experiments made have been reported in the newspapers as highly successful; but not having been present ourselves, we cannot attest the correctness of the statement, which theory would lead us strongly to doubt.

It will be observed, that by this arrangement the paddles, as they *ascend* out of the water, are subjected to precisely the same amount of resistance, as the common wheels wherein the paddles are *fixed*, by having to lift the tail or back water; and if the wheel be made to revolve rapidly, the centrifugal force will prevent the paddles, as they *descend* into the water, from assuming the vertical position, (as shown in the drawing,) consequently no advantage will be gained. But we will suppose the wheel only revolving at a moderate rate, still the centrifugal force will, to some extent, counteract the effect of the loaded paddle, and to this must be added the resistance of the water against the loaded part of the paddle which first strikes it; sufficient, together, we should imagine, to throw the paddles into the radial position, and cause them to encounter the same resistance as in the ordinary wheels.

In paddles of the form delineated, (fig. 2,) the patentee states the resistance of the water to the upper and lower portions to be equal. In the construction of water-wheels, a cylinder of the diameter of the discs occupies the space between the two rims.

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requested to bear this circumstance in his mind, and consider which of the two modes of revolving will produce the greatest effect in propelling. We have stated in the text the apparent defects of the mode delineated; by the reverse mode, preferred by Mr. Skene, it does not appear to us that he will profit any thing. It is true that he will avoid raising the back-water, but he has, in consequence, to encounter the disadvantage of entering the head-water nearly horizontally, and the paddles lose their propelling effect immediately they get to their lowest point, the resistance of the water having then a tendency to turn the paddles round upon their axes. We are supported in our view of the subject by a statement appended to the description, p. 479

Since the foregoing was written, the perseverance of the patentee in his undertaking, led to the performance of several public experiments on the river Thames, which, from being very erroneously reported, and absurdly commented upon, in the newspapers, excited a great deal of public attention; we have accordingly thought it right to annex to our description, some information furnished to us on this head, from Mr. James Murdock, (the mechanical draftsman and civil engineer,) on whose judgment, candour, and talent, we place the greatest confidence.

"The experiment was made on Wednesday, Nov. 19, 1828, on board the Sons of Commerce, Gravesend steamer; she was fitted with two of the patent wheels, each of which had 24 paddles, ranged in three rows, the paddles measuring 16 inches by 16, and their extremities describing a circle of nine feet eight inches in diameter; they appeared to be immersed about two feet six inches. Before starting from Blackwall, the paddles had been lashed to the arms of the wheels, by which means their action was the same as that of ordinary paddles; this was done, in order to show the comparative effect of the ordinary paddles with the patent ones; and, on arriving in Woolwich Reach, the boat, with the paddles thus arranged, was made to go a distance of six miles, by passing backwards and forwards three times, between two posts on shore, situate one mile apart; this distance was performed in one hour, eight minutes, and thirty seconds, the engine doing forty strokes per minute. The stops on the arms of the paddles being then cut, the same distance was performed by the patent arrangement in one hour and ten minutes, the engine doing 45 strokes per minute; the ebb tide was running during the whole time, and there was a fresh breeze, nearly right down the Reach, although it was rather less towards the close of the experiment.

The back-water was excessive in both arrangements, and the only difference I could perceive was, that the patent paddles threw the back-water right astern, whilst the ordinary arrangement caused the swell to extend rather on the quarter of the vessel. The paddles in

turning seemed to strike the arms and the rim of the wheels with great violence, causing an unpleasant noise. The vibration of the vessel was certainly greater with the patent paddles, the paddle-box being in a continual tremor. In respect to the power of backing astern, in which it has been supposed they are deficient, we had occasion to back the vessel, and I could perceive but little difference in the action."

Mr. Stevens has recently adopted a more simple modification of his apparatus, by having only one paddle to each throw of the crank, which must, we think, increase its strength and durability, and render its action more uniform.

Patent Method of Propelling Vessels, by William Hale, of Colchester. 1828.

The object of this patent is to impel steam vessels by means of a stream of water forced out astern, at a considerable depth below the water line, and thus dispensing with paddle-wheels, which are considered both unsightly and inconvenient.

a is a cylinder closed at top, and having a grating at bottom, which serves to keep out weeds, &c. This cylin-

der is firmly secured to the bottom of the vessel, so as to have free communication with the water, whilst the water is prevented from entering the ship or vessel by caulking, &c.; the top of this cylinder must not be above the water line; *b* is a screw of two or more threads, very nearly but not quite in contact with the sides of the cylinder, and revolving upon a spindle in a socket at *c*; *d* the shaft by which the screw is caused to revolve, driven by the band-wheel *e*, and turning in a stuffing-box *f*; *g* a pipe leading from the upper part of the cylinder, through a hole in the lower part of the vessel's stern; *h* the water line.

By causing the screw to revolve with rapidity, a stream of water is drawn through the cylinder, and forced out astern, through the tube *g*; by the resistance of the surrounding fluid the vessel is forced forward. The patentee also purposes to produce the same effect, by substituting pumps for the screw, keeping the upper parts of the pump cylinders below the water line.

The inconveniences attending paddle-wheels are so numerous, as to render an effective substitute for them, and free from their defects, one of the greatest desiderata in steam navigation; but no method hitherto proposed has been at all comparable to them in point of power. The present, or very similar plans, have been before frequently suggested.

In the commencement of steam navigation, a Mr. Linaker, of Portsmouth, purposed to lay a pipe along the bottom of the vessel, with valves opening towards the stern, and to expel the water by the direct action of the steam, as in Savery's engine, instead of employing pumps; and, in 1820, Messrs. Lilley and Frazer obtained a patent for propelling vessels by means of pumps, which should receive water at the bows of a vessel, and discharge it on the quarters. As for the screw, it has been, as we before observed, frequently purposed, though not in the position chosen by the patentee, but placed horizontally at the side of the vessel, where, from the obliquity with which it struck the water, sufficient speed could not be obtained; but as the present patentee, Mr. Hale, says a pump may

be substituted for it, we cannot expect greater effects from it than from the plans beforementioned. We therefore apprehend that the present mode of propelling with paddles must still continue, notwithstanding their radical defects, and with merely some improvements in their construction.

Patent Propelling Machinery, by J. L. Stevens, of Plymouth. 1828.

In this invention, a series of paddles are attached to a three-throw crank, and by means of radius and guiding rods, they are made to describe in the water the segment of an ellipse.

The figure represents a side elevation of the machinery, as it appears in a paddle-box, fixed to the side of a steam vessel, from which it occupies the same space as would be required by a common wheel of proportionate size; *a* is

the centre of the axis of the crank c c c, and b is one of its bearings, supported on the side frame of the paddle-box; *d d* (represented by two dotted horizontal lines,) is one of the longitudinal beams which support the other bearings of the said axis; and the extremities of *d d* are transverse beams to support them. In the paddle-box provision is made for the occasional rise of the rods *g* and *f*, if it be not thought desirable to carry the paddle-box above them; *e e e* are three sets of paddles, each set being carried by a division of the triple crank, which revolves between, and has its bearings upon parallel bars; the paddles are directed in their appropriate motion by means of the guide rods *f f f*, and the radius rods *g g g*, the latter of which work on a fixed beam or centre at *h*; *i i i* are arched spreaders, to keep the paddles steady and firm; the paddles are marked *r*, and are fixed to vertical bars in the ordinary way; the upper ends of the bars being inserted in sockets cast in the paddle carriage.

It must be understood (for the engraving does not show it,) that each throw of the crank revolves between two parallel bars, with its bearings upon them, and carrying with them a set of paddles. There are thus four bearings, the innermost of which is fixed to the vessel's side, and the outer one on the frame of the paddle-box. The circle of motion described by the triple crank being equally divided (120° apart) between each throw, they balance each other on their general axis.

The inventor does not confine himself to this precise arrangement, as it may be deemed desirable to lessen the number of paddles on each set, give them greater depth, and increase their stroke in the water, by shortening the guiding bars *f*; by which the weight and expense of the machinery would be greatly reduced.

Among the advantages presumed to be obtained by this very ingenious invention over the common wheel, the following are mentioned as the most prominent:—

The inventor's paddles work nearly in a vertical position, due allowance being made for the impetus of the vessel, and thereby save the power that is now consumed by the descending and ascending paddles on the common wheel.

From the peculiarity of their motion, describing in the water a segment of an ellipse, and not that of a circle, his paddles may be considerably deepened, and the length of their stroke increased, so that, occupying an equal space from the vessel's side as the paddles on the common wheel, their application of power is greater and in a much better direction, avoiding much of the unpleasant vibration, and consequent wear and tear in the vessels and engines; and also the back-water, which is dangerous to boats, and has hitherto been the chief obstacle to the introduction of steam vessels upon canals.

The patentee also calculates upon a great reduction of friction, and consequent durability and comparative cheapness; greater simplicity of construction, allowing of repair, unshipping and replacing at sea, besides admitting of the paddles being kept clear of the water, when using her sails only; the machinery being easily taken to pieces, and packed in a small space, additional sets may be conveniently taken on long voyages; an accident occurring to one set (on either side,) it may be disengaged, and the others worked until it is made ready for use.

That Captain Ross, R.N. author of a work recently published on Steam Navigation, entertains a favourable opinion of this invention, will appear by the following extract from a letter addressed to the patentee by the scientific navigator.

"I have no hesitation in declaring, that it appears to possess very considerable superiority over all the methods which have hitherto been adopted. In theory, it is perfectly accordant with philosophical and mathematical laws, and I have no doubt that in practice it will be found no less consistent."

The advantage of placing so many paddles upon each throw of the crank, we cannot discover; very little additional resistance can be gained by it, while it introduces complexity, increased expense, and various inconveniences. The invention is in other respects valuable, as, by the mode of the paddles entering and quitting the water nearly perpendicularly, the power of the engine is

not wasted by the resistance of the water in the wrong direction to the impelling force.

Since the foregoing was prepared for the press, several experiments have been made with Mr. Stevens's apparatus, on the City Canal, and elsewhere, with the most gratifying success; the paddles entering the water in the most gentle manner, and causing no more ripple in leaving it than oars would do; whilst a common paddle-wheel, which had been fixed to one side of the boat, to contrast with the improved paddle, threw the water over the boat's gunwale. The area of the surfaces of both the paddles were alike, yet the superior effect obtained by the application of the power to Mr. Stevens's, was proved by its turning the vessel round when the helm was let go, that is, making the external circle, and the common paddle the internal one.

Propelling Apparatus for Steam Boats, by Mr. Jonathan Dickson, of Holland Street, Blackfriars.

A few years ago, the above-mentioned person introduced to the notice of the Society of Arts, a method of raising and lowering the propelling apparatus of steam boats, without stopping the engine or any part of the machinery, and thereby allowing them to enter at pleasure just so deep into the water as may be found necessary for propelling the vessel at its intended velocity. This he accomplished by means of a sun and planet wheel motion being given to the second motion of the machinery, which causes it to move partly round the first motion, or driving power.

It was considered that this contrivance would be found of great utility in those steam vessels that carried sails, and afford to such the means of going to sea; for instance, suppose a steam vessel to be going direct against the wind by means of the whole power of her steam engine, and that the wind should change and become favourable, the propellers may by these means be immediately raised out of the water, and the vessel allowed to have the full effect of the sails, thereby saving the expense of fuel. The impediment of the paddle-wheels, to vessels of the ordinary

construction, is such as to render sails rather an incumbrance than an appendage of utility. Another advantage appeared to result from Mr. Dickson's invention, when there might be only a gentle breeze in the vessel's favour, as the propellers might be set to work so as to take hold of the water at pleasure; and thus, by uniting the power

of the wind to that of the steam, make greater progress in a given time, and at much less expense, as the engine will only consume fuel in proportion to the labour it has to perform. A further advantage would be derived when the vessel has only a side-wind, as one of the propelling wheels could be worked with its full power in the water, and the other lifted out, if necessary, (still the whole might be kept in motion, and thereby the direct course of the vessel be maintained); and if a vessel should lose her rudder, it is obvious she might be steered by the varied action of her paddle-wheels. In navigation, critical circumstances sometimes arise, wherein a sudden tack will save a vessel from destruction, which this vessel seems well calculated to perform, as she could be made to turn nearly upon the centre of gravity.

The figure represents a transverse section of the boat; 1 1 the sides of the vessel; 2 2 the float-wheels, impelled by the engine acting on their shafts A B, which have upon each a toothed wheel, that acts upon other toothed wheels fixed on the axis of the float-wheels.

Each float-wheel is hung on a pair of levers 3 3, turning on centres that are coincident with the axis of the first-mentioned toothed wheels; so that, although the levers are elevated at one end, and with them the float-wheels, yet the relative distances of the two toothed wheels are preserved; the one having what is called a planetary motion round the other. The left-hand float-wheel in the figure is shown dipping into the water, while that on the right hand is lifted out of it, by the action of the winch *e*, which communicates motion through two small wheels and pinions to the barrel 4 4, on which are coiled the chains attached to the ends of the levers 3 3.

Propelling Apparatus, by John Melville, Esq. of Upper Harley Street. 1829.

These improvements are intended to apply to the propelling of vessels by steam or other power, in a direct line, in such a manner that the propelling apparatus shall

be little or no impediment to the progress of the vessel when under sail; thereby obtaining the advantages of motion, either by the use of sails or steam power.

The patentee has three methods of effecting this object, which he purposes to use jointly in pairs, or severally, as

circumstances, connected with the size, form, and stowage of the vessel, may render most advantageous.

The method which he first describes, and therefore denominates his first method, consists in placing on each side of the vessel two pair of folding paddles, represented by *a a*, fig. 1; the other two pairs being precisely similar, but situated on the farther side of the vessel. These folding paddles are made of any suitable material, metal or wood, and of a size proportionate to the size and required speed of the vessel. The paddles are so attached by hinged joints to the prolonged axes, *e*, of the traversing frames, that they fold or shut up, and present only the sharp edges of their hinges to the water, when moving forward, or from stern to stem; and open, or expose a large surface to the water when moving backwards, or from stem to stern; being prevented by the stops from expanding beyond any assigned angle, as 145°. The traversing frames are keot to the side of the vessel by grooved guides *g h*. These paddle frames are furnished with friction rollers *i i*, at their ends, and at their middles, to keep them steady, and to facilitate their motion in the guides. The upper parts of the paddle frames consist of racks, which are acted upon by the toothed wheels shown, the axes of which pass through the vessel, and terminate in similar wheels, which act upon traversing racks on the opposite side of the vessel. To the piston rod of the steam engine, whose cylinder (which may be either situated above or below the plane of the axes) is placed in a position somewhat inclined, as represented by dots, is attached a rod which passes under a pinion on the axis of one pair of the wheels, and over a pinion on the axis of the other pair of wheels, and *vice versa*. The parts of the rod passing under the one and over the other of these pinions, and thus, by the alternating motion of the piston of the engine, cause one pair of the paddles to move forwards, while the other pair are moving backwards, by which one pair of the paddles on each side are kept continually in action. The paddle stems or axes are attached by stop hinges to the upper part of the paddle frames,

and to the lower part by screw bolts, to fix them when in use; by this arrangement, the paddles can be unshipped, and removed from the side of the vessel, whenever the state of the wind renders their application unnecessary.

The second method consists in attaching similar folding paddles to the ends of two or more rods projecting through stuffing-boxes, under the water line, in the stern of the vessel. These projecting rods, represented by *k l*, fig. 2, made of metal, and turned cylindrically, are connected with the piston of a steam engine, through racks and pinions, in a manner similar to the connexion of the paddle frames before described. The intention of the wheel and pinion, the former acting on the racks connected with the projecting rods, and the latter being acted upon by the rack connected with the engine piston, becomes necessary to obtain a greater velocity in the paddle than could be given to the piston of a steam engine. The projecting rods have rule joints at the extremities nearest the vessel. When one of the screw bolts is withdrawn, and the rods being detached from the rack, then pushed out beyond the usual extent, and the end to which the paddle is attached elevated to admit of the paddle being easily detached, the rod is to be let down and withdrawn, till it is all within the vessel, except its end, which must be left in the hole or stuffing-box, to prevent leakage; so that with this application there need be no exterior appendages, except when the paddles are in action. Fig. 3, is explanatory of this operation.

The third method consists in employing a double-acting pump, represented by *a b*, fig. 4, which receives the water by the supply pipes *c d*, furnished with valves *v v*, opening inwards, and conveyed through the pipes *i k*, to the air vessel *h*, where the valves *v v*, prevent its return; and it is then discharged, with increased velocity, through the eduction pipes *f g*, whose apertures at the stern of the vessel are diminished in proportion to the velocity required, and have the form best adapted for the discharge of fluids.

The piston rod of the pump, which passes through a

stuffing-box at each end of the cylinder, is connected with the piston rod of the steam engine, the cylinder of which is in a position parallel with that of the pumps. Supposing the pump piston moving in the direction from *a* to *b*, the water will be received into the cylinder through the supply pipe *c*, and the water, which had been previously admitted into the cylinder through the pipe *d*, is forced through the pipe *k* into the air vessel, and thence through the eduction pipes.

The patentee states, that being aware that attempts had been made by others to apply folding paddles, as well as the issue of water through pipes, he does not claim the exclusive use of these means, but simply his improvements in the employment of them, which we have described.

Propelling Paddles, by Orlando H. Williams, of Gloucester. 1829.

This inventor appears to have two objects in view:—first, to have the means of increasing or diminishing the surface of the paddles, according to the depth of the vessel in the water; and, secondly, to have the means of making them enter and leave the water edgeways. The first of these objects he purposes to accomplish by the application of the introduction of double leaves to the paddles, which are attached by bolts to projecting arms or radii from the paddle-wheel, so that one of the leaves may be shifted beyond the other, when more surface is required; and the second, by causing the paddle arms, through the medium of cams fixed upon them, and acting on projections fixed on the side of the vessel, to turn so that their broad surfaces may in succession be made to act on the water, when completely immersed in it, or during about one-sixth part of their revolution.

Propelling Paddles, by Archibald Robinson, of Liverpool. 1829.

This arrangement consists in placing the floats on the paddle-wheels, so that they may make, with the plane in

which the wheel turns, an angle, varying from 40 to 70 degrees, according to the extent of the paddle surface required; but it is preferred, under ordinary circumstances, to place them at an angle of 45 degrees. The exterior edge of the vanes slope back, or towards the stern of the vessel on each side; and thus, though they act upon the water obliquely, the oblique action of the one will counteract that of the other, and their united tendency will be to propel the vessel right a-head. Mr. Robinson considers, that by this arrangement he will obviate the inconvenience and waste of power arising from the violent action of paddle-wheels of the usual construction.

The same inventor claims in his specification, an improved method of raising and lowering, at pleasure, the paddle-wheels in the water, which he purposes to accomplish by attaching them to frames, whose ends are supported by chains passing over pulleys, and supported by counterpoises, so that the paddle-wheels, which are turned by spur-wheels fixed on the main axis, taking into similar spur-wheels fixed on their own axis, may be raised or lowered with any power sufficient to overcome the friction.

Propelling Apparatus, by Francis Neale, of Gloucester. 1829.

Mr. Neale proposes the application of hinged paddles, attached to a reciprocating frame, so as to fold upwards, or assume a horizontal position when moving forwards, and fold down or assume a vertical position, by which their flat surfaces act upon the water when moving backwards. The frame is made to traverse by a crank, acting upon a system of levers, similar to that called the lazy-tongs, with the addition of stays, on the principle of the radius rods of the series of levers used to produce parallel motion in the pistons of steam engines.

The foregoing patent has a great similarity to a suggestion by an anonymous correspondent, inserted previously, in the Journal of Patent Inventions, No. 63.

The following cut will serve, in a degree, to illustrate both.

The writer states that he was led to devise this mode of propelling, by observing the powerful action of a fish's tail; it is thus described:—

"The piston of the engine being attached to the rod A, will alternately open and shut a series of sliding submarine fins or fans, which may be variously constructed, and placed either at the sides, or bow and stern of a vessel, keeping up a constant pressure upon the water, and a consequent motion of the vessel forward, without backwater or splashing."

Patent Propelling Apparatus, by Mr. E. Galloway. 1829.

The proposed improvement we have now to describe is an invention of the author of the first part of this work. The object of it is similar to most of its precursors,—that of providing a remedy for the loss of power, and other inconveniences arising from the oblique position in which the float-boards of the common paddle-wheels enter and leave the water. This he purposes to effect by causing each float-board to turn, or rather vibrate on an axis, at its edge, next the centre of the paddle-wheel, through the medium of projecting levers, firmly fixed to the float-boards, at their axis of motion, and connecting rods pro-

ceeding from the extremities of these levers, to the extremity of a *fixed crank*, adjustable at a given distance from the centre of motion of the paddle-wheel, which consists of four radiating arms, connected at their extremities by strengthening braces.

The annexed engraving will afford an idea of the leading features of the apparatus; but we understand it differs, in some respects, from that actually employed by Mr. Galloway in the Confiance, Government Steam Boat, which is now being fitted with paddles on this principle.

b b represent four arms radiating from a central axis, the extremities of which *e e*, are connected by bracing rods from

one to the other; *c c*, are the paddles, firmly fixed to which are the levers, *d d*, forming angles of about 120 degrees with each other, and turning together on axes at *e e*; *f*, represents the water line; *g* is the crank, fixed centrally to the axis of the wheel, but so as not to revolve with it; this crank is alterable at pleasure, by means of a set screw, which causes the paddles, through the medium of the connecting rods *i i i*, to take such an angle with the water line, as may be deemed most desirable for propelling; the rods *i*, however, are connected to a revolving collar on the crank, which allows of their free rotary motion, while it draws the paddles uniformly into the positions shewn in the engraving, when the arm of the crank is set in a horizontal position, as represented. The dotted lines shew the position the paddles assume in the intermediate parts of their revolution, or the relative position they would take, if there were eight paddles attached to the wheel.

Poole's Patent Steam Boat Paddles. 1829.

Owing to the great surge occasioned by the action of the common paddle-wheels, the application of steam power, for propelling boats on canals and narrow rivers, has hitherto generally failed of success. On the river Witham, in Lincolnshire, however, three steam boats are worked by Mr. Poole's paddle-wheels, with great advantage; as the action of the *paddles* is such, as to cause no sensible additional swell of the water, beyond that produced by sailing boats, at the same speed. The following description of the apparatus is extracted from a letter received by the author, from Mr. Merryweather, of Lincoln Castle.

"The wheel is a common one, to be suited to the size of the vessel it may be designed for, except that the float or paddle is not fixed to the radii, but vibrates on its axis in the rims of the wheel. On the side of the vessel is placed, *very securely*, two concentric circles of iron, placed vertically edgeways, with a space of about one inch and a half between them, forming thereby what may be called a rail-road, on the side of the vessel for a guide-pin,

fixed on the end of a lever, attached to the paddle axle to travel in. The concentric circles before mentioned, are placed *eccentric* to the axle of the wheel, and the paddles are thereby carried round, so as to enter and leave the water in such angles as to avoid the splash at entering, and the lift at coming out. This wheel allows advantageously of a deeper immersion in the water than the radial paddle, obtaining a greater power by being brought to a leverage on a denser medium than the surface water, and thereby adding most materially to the propelling power of the wheel; it is equally efficacious in its back stroke. It should seem, however, that one-third of the diameter of the wheel, from present experience, is the best dip, and as this may allow of the lowering of the main axle, and probably the reducing of the wheel, in consequence of the greater extent of paddle surface that can be employed, the paddle boxes may be considerably lowered. The angle formed by Mr. Poole's arrangement, we know has been obtained before by Mr. Steenstrups, Mr. Oldham, and others; but it has hitherto been the result of intricate trains of wheels, endless chains, &c. &c.; the expense of making which, the loss by friction, the liability to injury, and the difficulty of reparation in complex machinery, are very sufficient reasons why their inventions have not been carried into practice. The same beneficial angle, however, is got by Mr. Poole's eccentric rail-road, and is obtained by a mere lever connecting the paddle axis and the rail-road, which is traversed, as the wheel is driven round by a guide pin, at right angles to the end of the lever; and to prevent the noise, which was found to proceed from friction wheels, pieces of thick sole leather, cut round, with a hole in the centre, are kept upon the guide pin, and screwed together upon it, so tight and hard, as to bear the friction of the rail-road circles, without injury, for a great length of time, and which quickly assume a hardness and polish with use, that will almost defy wear. This is a subject in which I am much interested, being one of the Committee of Management of the River Witham, who are most anxious to give every

facility in their power to steam vessels navigating the Witham, though they are compelled, from the present structure of the vessels, to limit the rate of speed to 4½ miles per hour, in the first nine miles from Lincoln, for fear of injury to the banks, in consequence of the reduced scale of that part of the river.

*Description of Steam Vessels navigating the River Witham.**

Names of Packets, and when Poole's new wheels were attached thereto	Length of keel	Width of beam.	Horses' power of engine.	Draught of water when light.		Dead weight of engine, machinery, boiler & water therein.	Average speed with old paddles.	Average speed with new paddles.	Consumption of coals with old paddles.	Consumption of coals with new paddles.
	Feet.	*Feet.*		*Ft.*	*In.*	*Tons.*	*Miles.*	*Miles.*	*Bushels.*	*Bushels*
Favorite, July 27, 1829..........	67	10½	8	2	8	9	5	6	40	32
Countess of Warwick, Sept. 22..	68	10	10	3	3	11	5	6	40	32
The Witham, December 6......	74	12	9	3	3	13	4½	5½	48	40

a b c d e f, as shown in the engraving in the subsequent page, are the paddles, which turn round upon their axes as the large wheel, to which they are applied, revolves. *h h h h h h*, are tie rods to the two sides of the wheel. *i i i i*, are the concentric rings, with an opening or groove between them, which forms the path or railway for the cranked arms, *k k k*, to travel in. The centre of the guide rings or railway being eccentric to that of the wheel, causes the paddles to assume the positions repre-

* The average speed in the above Table must not be looked upon as what only can be accomplished, the *limit of speed,* before mentioned, being the occasion of it. In the lower part of the river, where the width is from 90 to 100 feet at surface, and seven to ten feet deep, the *Countess of Warwick* can go *eight miles* per hour well, *on still water.* The *Witham,* when put down by loading to four feet, which she has been, goes surprisingly better; thereby showing the advantage derived by a deeper leverage. The consumption of coals stated, is in going down to Boston one day, and returning the next.

sented, which are found to be best adapted to the motion of the vessel. The paddle *c*, is supposed to be just dipping into the water, while *d* is deeply immersed, and *e* is just emerging from the water.

Fig. 2, gives an underside perspective view of a paddle separately, *k* being the cranked arm, connected at one end to the axis *a*, and at the other to the anti-friction roller before mentioned, which travels in the groove of the railway.

Patent Propelling Apparatus, by Mr. Jacob Perkins. 1829.

On the same day as the last-described invention was enrolled, Mr. Perkins deposited his specification of the following mode of propelling, which is materially different from all others that have preceded it. Mr. Perkins places each of his paddles on the extremity of a radiating arm, in such a position that its plane, if produced towards the centre of motion, would make with the axis of the paddle-wheel an angle of 45 degrees. The axes of the paddle-

wheels are not carried across the vessel in the customary manner, but are carried in a direction sloping towards the stern, and they meet at a point in a straight line, drawn from stem to stern along the middle of the vessel, making with it an angle of 45 degrees, and with each other an angle of 90 degrees. On the extremities of the axes are fixed bevel-wheels, which act upon each other, or are both acted upon by an intermediate bevel-wheel in connexion with the steam engine, or first mover.

By this arrangement, the surface of each paddle, when immersed in the water at its greatest depth, is perpendicular to the side of the vessel, or to the line of motion, as represented at *c*, fig. 1, in the annexed cut; at their greatest elevation, each paddle is parallel to the line of motion, as at *e*; and, when in the horizontal position, whether ascending or descending, the paddles present an angle of about 45 degrees; and from this angle it deviates but little, when in the act of entering or leaving the water, as the patentee purposes to immerse the wheel to about one-fourth of its diameter.

Fig. 1.

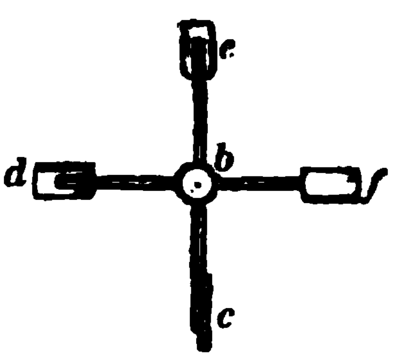
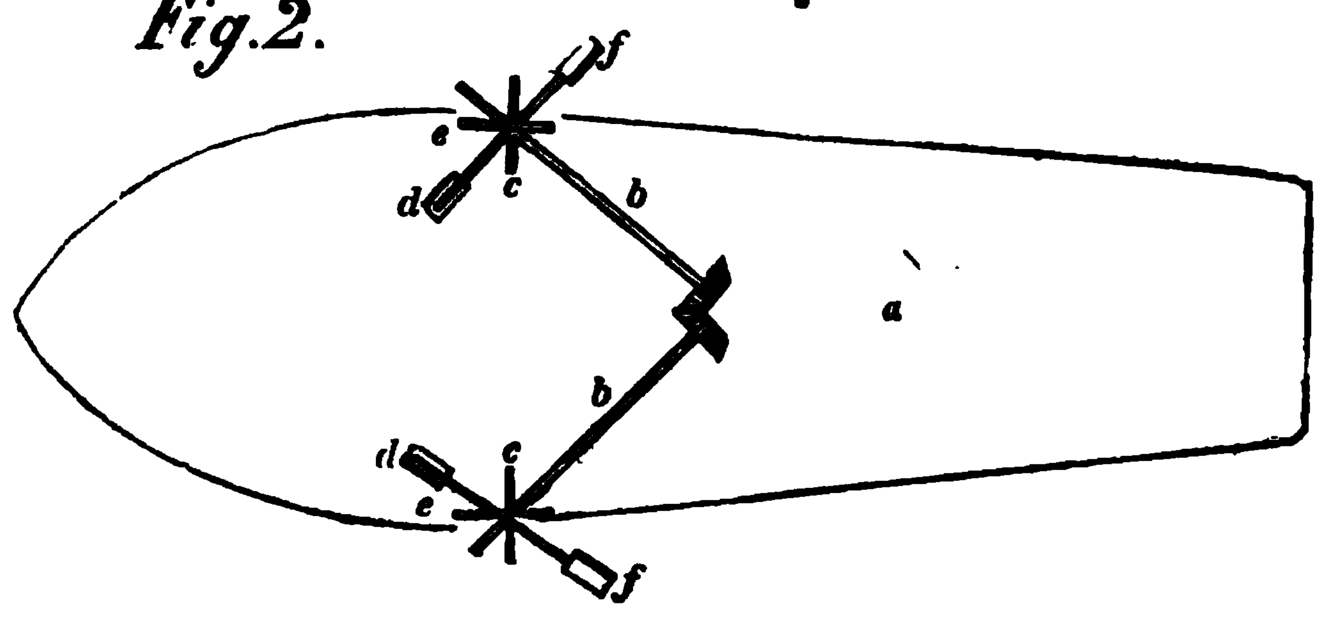


Fig. 2.



The diagram fig. 2, is intended to represent the outline (in plan) of a vessel with these paddles attached. *a* the

boat; *b b* the paddle axles, to which a uniform motion is given by the engine, through the medium of the bevel gear which connects them; *c c* are two of the paddles immersed in the water, and in the act of propelling; *d d*, *e e*, and *f f*, are those paddles which succeed each other in the revolution. The oblique action of the blades of the paddles, as they perform their revolutions, will be understood by reference to fig. 1, before explained, wherein the paddles are marked by the same letters as in fig. 2, to which, therefore, the observations already made will apply.

By this method of causing the paddles to enter and leave the water in an oblique position, it is presumed that the agitation of the water will be very slight, and the consequent loss of power proportionally trifling; and it will readily be admitted, that paddles of this construction have the important advantage, of being equally simple, a circumstance which will render them as durable as those of the ordinary construction. On the other hand, it has been contended, that a considerable portion of the power employed, is wasted by the oblique position in which the paddles are made to revolve; on the ground, that if this obliquity "were carried to the extreme, (and there can be no maximum of effect obtainable by limiting it to 45, or any other number of degrees,) it would entirely prevent the agitation of the water, at the very moment when the motion of the wheels would entirely cease to have any effect in propelling the vessel."

The writer of this remark does not appear, however, to have taken into his consideration, that by the diminished resistance of the water, owing to the oblique action of the paddles, they will rotate quicker; the loss or gain will then be as the increased friction of the latter, is to the waste of effect by the radial position of the common paddles. We annex an account of some experiments made with Mr. Perkins's paddles, recently published in the Journal of the Franklin Institute, which, if correct, exhibits the invention in an important point of view.

"Those who have witnessed the Chinese method of sculling, must be strongly impressed with the superiority of

that over the European application of the oar. The action of Mr. Perkins's wheel is not unlike that of the Chinese scull; in fact, the only difference is, that the motion of the scull is reciprocating, that of the paddle-wheel in question, rotary; the rotary motion being clearly preferable, inasmuch as the frequent change of motion in the scull, is so much waste of power.

"Comparative experiments with the common and with the newly-invented wheel alternately used in the same boat, have shown, that, even at a shallow dip, the most appropriate to the common wheel, there is a very important gain with the wheel of Perkins. But when the wheels are each of them immersed to one-third of their diameter, (perhaps an average dip for sea-going vessels,) the advantage attending this newly-invented wheel is scarcely credible.

"The experiments alluded to were made in the presence of an eminent engineer, and were as follows:—a boat was propelled by a weight falling a certain distance, attached to a line turning an endless band, running over a pulley fixed on a shaft connecting the paddle-wheels. Two sets of paddle-wheels, one on the common, the other on Perkins's principle, were put in succession into the boat. The two sets of wheels were nearly of the same weight, any little advantage in this respect being in favour of the common wheel. The boat moved round a basin of water measuring within 36 feet.

"*Old Paddles.*

"1st Experiment	6	rotations	216 feet	m 3'.40'
2d do.	5¾	do.	207	3.40
	11¾		423	7.20

"*New Paddles.*

"1st Experiment	15¾	rotations	567 feet	in 8'.16"
2d do.	15	do.	540	8.25
	30¾		1107	16.41

"In these experiments, the weight supplied the force of steam. They show that the same quantity of steam

steam will propel a boat with Perkins's paddles 1107 feet in 16'.41", which with the common paddles moved only 423 feet in 7'.20". The saving in fuel, therefore, appears to be upwards of three in five; 211½ being the moiety of 423, and 211 and a fraction being the fifth of 1107. Over and above the saving in fuel, these experiments show an increased speed of about 15 per cent. or a saving in time of nine minutes in an hour. For 16.41" : 1107 :: 7'.20"= 486, a gain of 63 feet on 423.

"Facts are stubborn things, opposed as they may be to the theories of men of acknowledged ability. It has been asserted by certain eminent engineers, that the common wheel admits of but little improvement. If it cannot be demonstrated that much power is lost by the common wheel, then would those engineers be borne out in their dictum. But recent experiments, in England and America, prove the loss of power with the common wheel to be very much greater than had hitherto been imagined. If the loss were trifling, could a single horse, on a towing path, do the work of a six horse engine in the boat? Could two horses, attached to the hawser of a boat moved by a 25 horse power engine, neutralise the power of the engine, stay the progress of the boat, and occasionally give her stern way? These facts, however, are well authenticated.

"Engineers, who believe in the perfection of propelling machinery on the old plan, exulting reply to these facts, by making abstract inquiries; such as, whether a vessel can move as fast as the periphery of the wheel by which she is propelled?—whether, if a boat move four-fifths as fast as the periphery of the wheel, it is not considered fair speed?—and then jump to the conclusion, that the whole loss of power cannot exceed one-fifth, and that, allowing for friction, it is absurd to expect to save much of that small proportion by any improvement. That this conclusion is premature, the following remarks are intended to prove.

"Let it be supposed that a paddle-wheel can be made of such power, and to have such hold on the water, as to

move only one-hundredth part faster at its periphery than the vessel it propels. The difference in such case between the relative velocity of the wheel and the vessel, would be as 99 to 100. It is true, the magnitude of the wheel would require steam power in proportion, and then the remedy would be as bad as the disease, but the case is practicable. To suppose, therefore, that the loss of power is only as the relative movement of the wheel and of the boat, is as absurd as it would be to assert, that inasmuch as the carriage-wheel and its body move with equal velocity, it matters not what load the carriage contains. In the one case, the speed or draught of the horses must be increased, so in the other must the steam power.

"We will consider the subject, however, in a more tangible shape. There are four kinds of water wheels, of which the undershot assimilates more to the paddle-wheel than the others; and the undershot wheel, it is acknowledged, loses two-thirds of its power; that is to say, if three pounds of water fall one foot on an undershot wheel, it will not communicate impetus sufficient to raise more than one pound to the height of the fall. Let us examine these data in three points of view, with relation to the paddle-wheel.

"1st. The undershot wheel is propelled by water descending on it.

"2dly. The water so falling is so directed as to strike the float-boards at right angles with their surface.

"3dly. Although the power is communicated by water moving at a quicker rate than the wheel, yet so soon as it has communicated a portion of its impetus to the wheel, that quantity of water left on the float-boards and hurried round with the wheel is dead weight, and serves only to impede the wheel's velocity, and so to diminish its power.

"In all these particulars, the disadvantages attending the common paddle-wheel are greater than those above described.

"1st. The water cannot descend upon a wheel revolving on a plane of water.

"2dly. The paddles do not strike the water at right

angles with their surface; yet the impetus given by the first paddle is the principal power, inasmuch as it is exerted on undisturbed water all the others moving in water previously disturbed.

"3dly. The inert body of water between the paddles, carried round by the wheel, must be greater than that taken up by the undershot wheel. And, above all, the backwater is far more considerable with the paddles than with the undershot wheel.

"Now, if the loss of power with the undershot wheel is allowed to be two-thirds, and it has been demonstrated that the loss by the paddle-wheel is greater than with the undershot, the result of the experiment herein stated will be the less difficult of belief, and efforts to improve the paddle-wheel be less open to be characterised as visionary and unprofitable.

"Mr. Perkins's improvements remedy, in a great degree, the losses of the common wheel, whether by indirect action or by backwater. The paddles are made to enter and leave the water edgeway; when at the lowest rotation of the wheel, their action is at right angles with the keel; each paddle enters into and moves in water undisturbed by any preceding paddle; and thus every paddle immersed is doing service, though in different degrees, at the same moment.

"The new paddles show the greatest proportionate advantage when one-third and upwards of their diameter is immersed. This degree of immersion would ordinarily amount to from seven to eight feet, instead of two, the advantageous dip for the common paddle. The resistance of water being so much greater at the depth of eight feet than it is at two, too much importance cannot be attached to this material distinction between the two modes of propelling—Perkins's paddle being made more in the shape of an oar-blade than of a float-board.

"As Perkins's paddles do not strike the surface of the water with their flat sides on entering it, the constant tremulous motion experienced in steam boats will be obviated. So violent is the concussion in a heavy sea with the

common paddle, or if the wheel be much immersed, that the destruction of the paddle, and even of the shaft, or parts of the connecting gear, are not unfrequent occurrences.

Apparatus for Propelling Steam Boats, by Adolph Heilbronn. New York, 1829.

Some experiments with this apparatus having been recently made at New York, which, it is said, were attended with satisfactory results, we are induced to include a description of it in this part of our work; we are, however, not very sanguine as to its success, the parts being too numerous, and very liable to injury and rapid wearing away, to last any considerable time in working order. Nevertheless, should Mr. Heilbronn succeed in establishing their utility or advantage over the common wheel, it is but right to notice, that Mr. James Dawson, of George's Place, Dublin, took out a patent for precisely the same invention, more than ten years previously, a full description of which is given in the forty-third volume of the Repertory of Arts, Second Series.

The revolving motion given to these paddles differs altogether from that which has been contrived with a view to their dipping into, and emerging from the water vertically. The paddles, or buckets, in Mr. Heilbronn's wheel, are each fixed upon an arm which radiates from the centre of the wheel, as may be distinctly seen by a reference to the engraving.

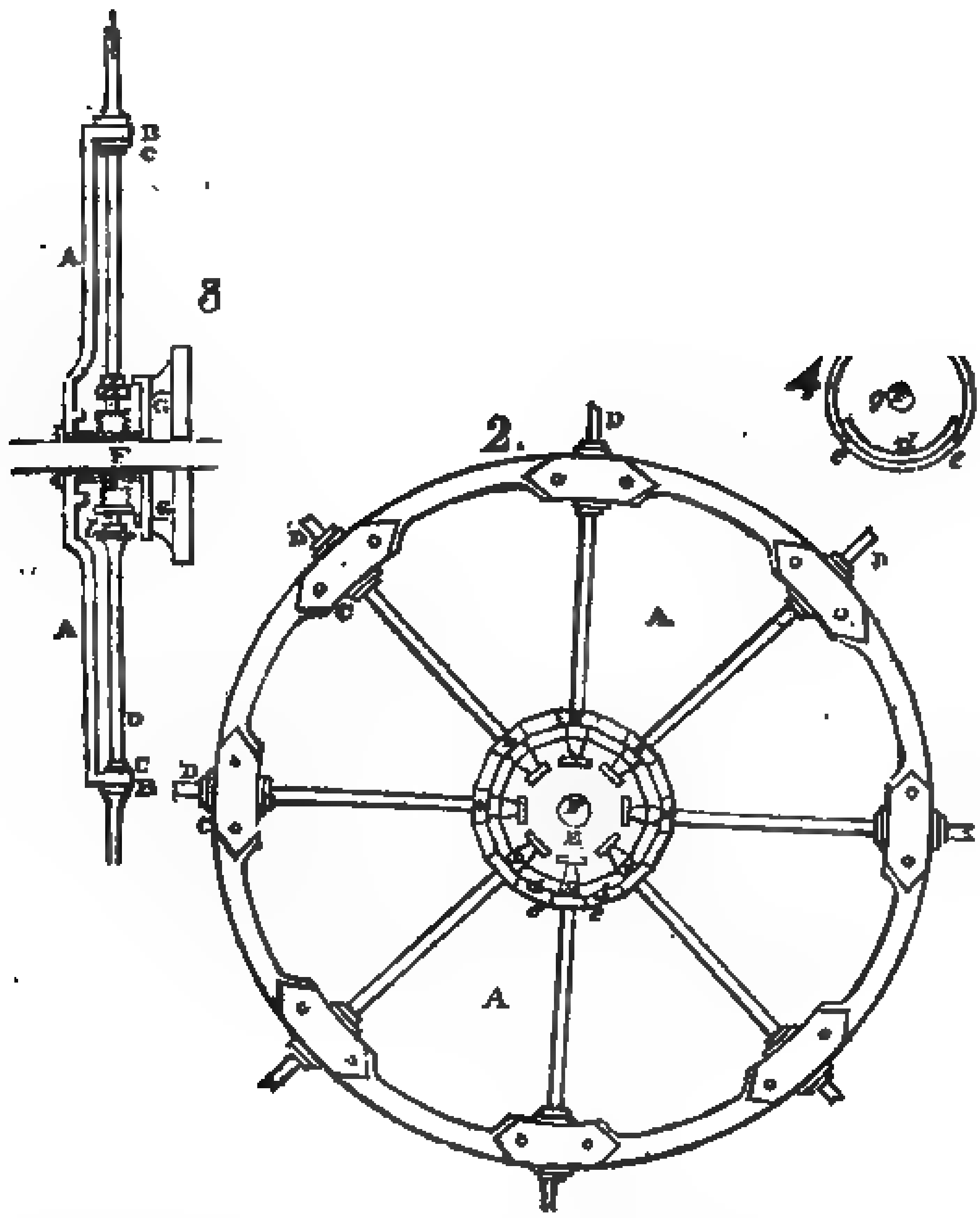
In a wheel so constructed, the paddles may be made to enter the water edgewise, and be turned so as to act upon it at any point which may be preferred. The paddles which are out of the water are all feathered, or turned edgewise, so as to experience but little resistance from the wind, and to require a very shallow box or casing to protect them on each side of the boat. A wheel of this description may be immersed in water to any depth which may be required, or it may be entirely under water, where the depth is sufficient: should such a mode of fixing it be

thought advisable, the progress of the boat will be but little impeded thereby.

One great advantage anticipated from these paddles is, the avoiding of those numerous and perpetual concussions produced by the striking of the water by the ordinary floats, which causes a continued, distressing, and very injurious tremulous motion. They enter by their edges, and are gradually brought into action.

The number of revolving paddles to be used will be best determined by experiment.

Figure 1, represents one of the said wheels of eight arms or paddles, as it appears when in a finished state, and as applied to the side of a vessel; and figure 2, is a view, on a larger scale, of the central part of the said wheel, as seen from the opposite side, or that nearest to the vessel, for the purpose of showing how the paddle-arms are held and supported in their places, and yet permitted to turn or feather at the proper instant, while the whole wheel turns round; and figure 3, is a section of the same part of the paddle-wheel, as is shown by figure 2, and likewise of the piece G G, which is called the wiper carriage, which is immoveably fixed to the side of the vessel, for the purpose of producing the turning or feathering of the paddles at the proper moment. In these several figures A A A A, is a circular disk or plate of cast-iron, having a rim or ring B B B, rising on one side to a sufficient height to give strength and solidity to the said circular plate, and also to take the brasses C C C, through which the paddle-arms or axis D D D D are permitted to turn. The central block of metal E, may be cast in one piece with the disk or plate, but will be better detached, and afterwards fixed to it by screw bolts, as shown in the section, fig. 3, because, when detached, the brass sockets, or steps *a a a a*, for receiving the inner ends of the paddle arms or axis, can be more accurately bored and fixed. The disk or plate A A A A, with its centre block E, forms the central part of the paddle-wheel, which must be firmly keyed, or otherwise fixed upon the main shaft F F, which derives its rotary motion from any



power applied within the vessel, and this shaft also passes freely through the centre of the metal wiper carriage G, which is firmly and immoveably fixed to the side of the vessel, for the purpose of operating upon the wipers or projections *b b* of the paddle axis, in order to produce the

turning or feathering of the paddles. To effect this, the outer face of the wiper carriage presents two annular surfaces, as seen at *c* and *d*, in fig. 4, (which is a front view of it,) and a part of them is cut away, as at *e e*, to a greater or less extent, according to the period at which it may be desirable to make the paddles turn or feather. The wipers or projections on the axes of these paddles, are projections of steel or other metal, crossing each other so as to project at right angles from the axes of the paddles, and as these wipers come into contact with one or other of the annular surfaces *c* and *d*, fig. 4, and also seen in fig. 2, the several paddle axes will each make a quarter turn or revolution. Thus the five wipers *z z z z z*, fig. 2, lie with their flat surfaces upon the annular surface *c* of the wiper carriages, but that surface is cut away between *e* and *e*, (as is more distinctly seen in fig. 4,) and the inner annular surface *d* then presents itself, and acts upon the wipers *z z*, to turn them round; consequently, the inner wipers *y y y*, will now assume the flat position, and will continue in it, until they are again brought, by the motion of the wheel, into contact with the ends of the outer annular surface *c*. It will thus be seen, that by enlarging or contracting the opening *e e*, fig. 4, and with it the inner annular surface *d*, that one, two, or more, of the paddles may be made to stand at right angles to all the rest, and thus that any number of paddles may be made to move through the air, and to enter into and come out of the water with their thin edges forward, while the remainder, or those that are under the water, will remain steadily in that position in which they are most effective for the purpose of propelling, as is distinctly shown by the manner in which the paddles are arranged round the wheel, as shown by fig. 1. It will be necessary to employ springs to prevent the blow and concussion, which would otherwise take place between the wipers, on the axes of the paddles, and the ends of the wiper carriage, upon which they strike, and by which they are turned round; and the best application of such springs, is to use those of the spiral kind, of considerable strength, and to introduce

them into round holes very nearly fitting them, and drilled in the ends of the wiper carriage which first comes into contact with the wipers. The spring being introduced into the hole, a cylinder of hard steel, just fitting the hole, is placed upon it, and there fixed by a pin driven through a chased mortise hole in the said cylinder, in such a manner that the said cylinder can fall wholly into the said hole when pressed upon, but without such pressure, will project about half an inch, or rather more, out of the said hole; and as the said wheels are so fixed as to require cases to protect them, as in ordinary steam boats, such cases may be formed of light iron-work, covered over with slight iron bars, or with strong wire-work, because such open-work cases do not offer the same resistance to the wind and water as close-boarded cases do; and moreover, they have the effect of much more effectually breaking the force of the waves when they drive against them. Bars or rods, with points upon them, are also fixed to the insides of such cases, causing the said points to come as nearly as possible to the paddles and paddle-axes without touching them, for the purpose of clearing off any weeds that may attach to the paddles, and likewise to protect them from striking against any timber, ice, or other floating substances, by which the paddles of steam boats are frequently broken or injured.

The claims of the inventor are, First, to the frame-work or wheel, as above described, for holding the patent paddles. Secondly, the introduction of springs to act upon the wipers. Thirdly, the paddle-box, made of open wire-work, net, or cross-bars, with projecting pieces, or points, to clear the paddles.

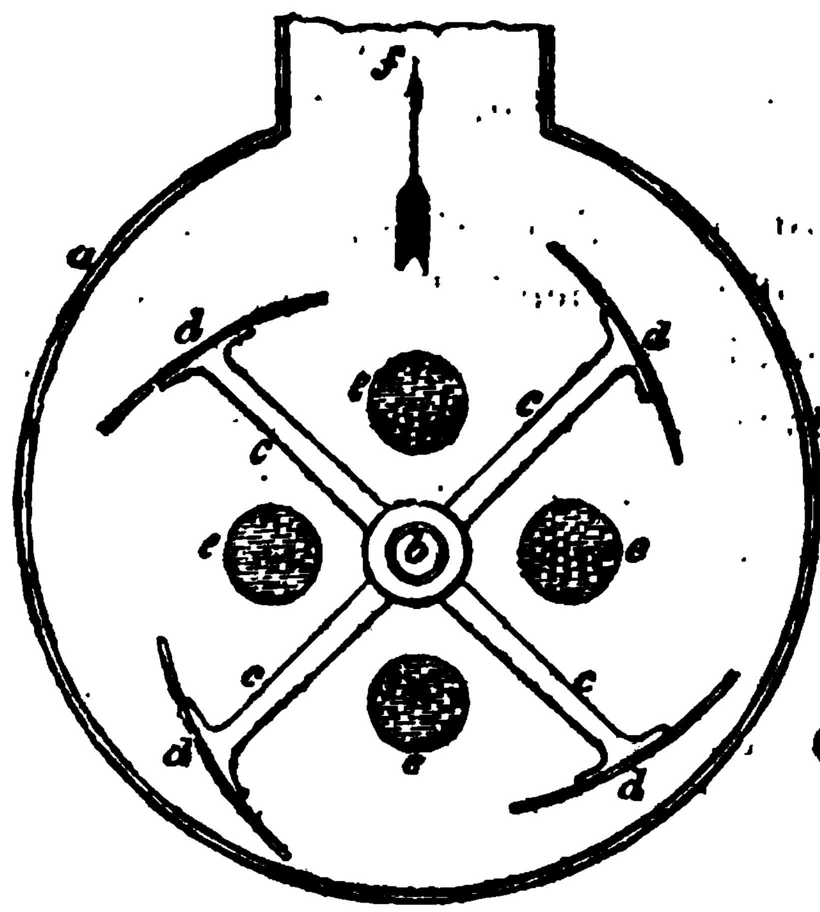
From the cautious wording of these claims, it is evident that Mr. Heilbronn was acquainted with Mr. Dawson's patent wheel. The latter gentleman, in his letter to the Editor of the Repertory, before alluded to, says, very candidly, "It has been fairly objected to wheels on the above construction, that they are expensive, complicated, and work with much more friction than common wheels," and to obviate these objections, he purposes an arrange-

ment of greater simplicity, of which a conception may be formed by the following description. Each paddle of this wheel is formed of two boards, posited at a certain angle, face to face, on their respective axes, leaving only a space sufficient for the free escape of the water between them; in this position they are retained by stops from opening further. When the wheel revolves, the water acting on the broad surfaces of the paddles, causes them to close as they enter the water, and to remain so until they begin to rise out of it, when the weight of the water lodging on the narrow surface only, causes them to open, and in consequence, the water falls through without being lifted.

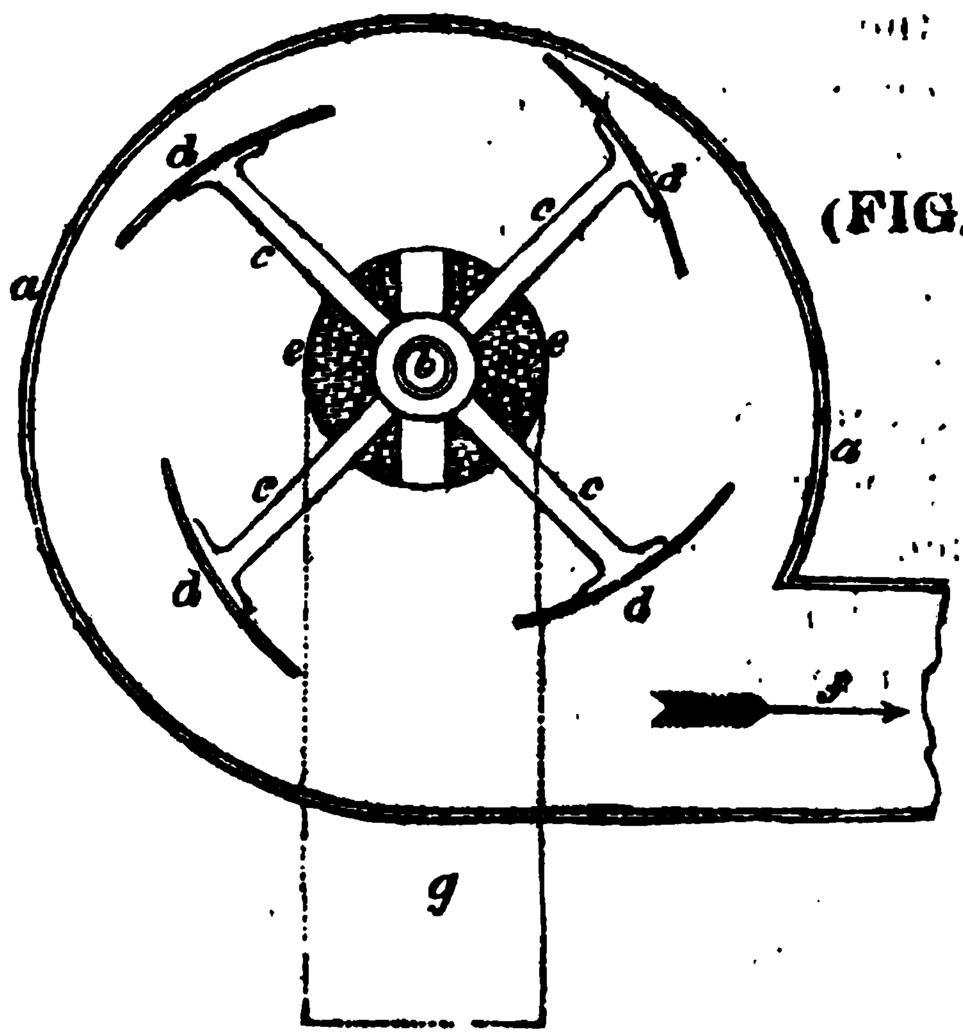
We should have given a diagram of this wheel, which has the merit of simplicity, had it afforded any effective means of backing astern; the water presenting scarcely any resistance to the backward motion of the paddles. This is a strong objection to its use; and there is another, namely, the concussions of the paddle-boards, as they successively come in contact in closing, an effect not easily avoided, without departing from simplicity,—a quality of the utmost importance in all machinery, but most especially in a paddle-wheel.

Patent Propelling Machinery, by William Hale, of Colchester. 1830.

Mr. Hale purposes to employ a paddle-box entirely filled with water, and made air-tight, except at the centre, where there are one or more apertures for the admission of water, and at the circumference, where there are one or more openings for its escape. The centrifugal force of the paddles acting on the water within the box, produces a pressure all round the interior of the box, which gives a tendency to move in a direction opposite to the side where the opening is made in the circumference; while the same cause accelerates the entrance of the water into the box, which is produced in the first instance by the paddle-box being placed within the vessel, and lower than the exterior water.



(FIG. 1.)



(FIG. 2.)

Fig. 1, represents one modification of the apparatus, and consists of an air-tight circular casing *a a*, containing four arms *c c c c*, which revolve horizontally on a vertical axis *b*, placed eccentrically with respect to the casing: at the extremities of the arms are fixed four curved vanes or paddles *d d d d*, inclined in the manner represented in the drawing. The water enters the casing through the holes *e e e e*, and is expelled by the revolution of the paddles

through the opening f, against the external water at the stern, which of course impels the vessel in a contrary direction.

Fig. 2, is another modification of the apparatus. In this, similar letters of reference indicate similar parts, with only these differences in the arrangement, that the water is received at one large aperture in the centre of the vanes, the line of direction of the discharge being a tangent to the circle. The dotted lines at g denote a tube leading from the bottom of the vessel, through which the water ascends into the paddle-box; and it may be supposed, that similar tubes are employed in the first described plan, for conducting the water into the paddle-box.

Another modification is represented in tne specification, in which the water is expelled through two apertures, instead of one; and it is stated, that the paddles may be either placed vertically or horizontally, according to the form of the space which they are designed to occupy in the vessel.

It is difficult to discover the advantages which the patentee expects to gain by these contrivances; we fear, that the power required to produce in a large body of water, such as the contents of one of his paddle-boxes, a rotatory motion of sufficient velocity to produce an available centrifugal force, would be too great to render the plan desirable in point of economy.

Method of Regulating the Movement of Steam Vessels, invented by Messrs. J. and C. Carmichael.

We shall now present our readers with a description of an apparatus which has been found very useful in reversing the motion of the propellers to steam boats.

The object of this contrivance (as described by the inventors,) is to regulate the motions of the steam vessel in a more easy manner than heretofore. By the simple motion of a small handle, or index, placed on a table, upon deck, in view and in hearing of the man at the helm, and of the master of the vessel, every movement which

the engine is capable of giving to the paddle-wheel may be at once commanded. The vessel may be moved forwards or backwards, or may be retarded, or entirely stopped, at any given moment, by merely turning the handle to the places denoted by the gradations of a dial-plate. No skill is required for this purpose; so that the master himself, or a sailor under his directions, can perform the office as well as the ablest engineer. Thus, the confusion which frequently arises at night, in calling out to the engineer below, is avoided, and any ambiguity, arising from the word of command being transmitted through several persons, entirely prevented. In point of fact, it places the engine as much under command as the

rudder is—an undoubted improvement upon the clumsy method of bawling out to the engineer below, who either may not hear, or may chance to be out of the way—circumstances which may lead to the most serious accidents.

"The different parts of the machinery are not exactly arranged in the sketch as they are executed in the said boat, but we hope that the principle will be better understood from having arranged them so as they can be better seen in the sketch prefixed.

"The cylinder and jacket are cast in one piece, connected at the bottom, but altogether disconnected at the top, when cast; the vacancy between the two is closed at the top by an iron ring, and hemp or rust packing in the joints. The steam from the boiler enters between the cylinder and jacket, by the branch A, fig. 1, passes round the cylinder, and communicates with the side pipe C, of the valve-chests, by the branch B, but cannot enter the cylinder when the steam valves D D, are shut. The eduction valves E E, are situate below the steam valves.

"The steam valve rods work through a flax packing at F F, and are made hollow, to allow the eduction valve rods to pass up the centre of them; they are also made air-tight by a flax packing at G G.

"The valve lifters H H H H, are fast upon the lifting-rods I J, only one of which can be properly seen; the foot of the one farthest from the eye is seen at the rocking-shaft. One of these rods lifts the upper steam valve and lower eduction valve, and the other the lower steam valve and upper eduction valve. The lower steam valve and upper eduction valve are represented as lifted in the sketch.

"The rocking-shaft K, turns and returns upon its centre about 40°, and having two spanners (or pallets,) L, projecting from it upon opposite sides, causes the lifter rods, and the valves connected with them, to rise alternately. The lifter rods fall by their own weight, and when the pallets are horizontal, all the valves are shut, and for an instant of time are at rest.

"The rocking shaft receives its motion from an eccen-

tric wheel M, fastened to the crank-shaft. The fixing of this wheel, with relation to the crank and valves, is a point of considerable nicety, as upon this depends the opening and shutting of the valves at the proper time.

"The eccentric rod N, is supported on the crank shaft by a projecting part on each side of the eccentric wheel, turned concentric with the shaft by the brass pieces O. The four rods P, pass through these brass pieces, and slide freely in them. This part is shown in the section at fig. 2, with part of the crank (or paddle) shaft, and the crank on one end. The other end of the eccentric rod is supported on the roller Q; and as the crank shaft turns round, the eccentric rod travels backwards and forwards, a distance equal to double the eccentricity of the eccentric wheel; and as the said rod is connected with the rocking shaft by the double-ended spanner R R, on one end of it, consequently the rocking shaft will travel from one extremity of its arch of motion to the other, in the same time that the crank shaft makes half a revolution, or in the same time that the steam piston travels from the top to the bottom of the cylinder, or from the bottom to the top. The steam piston is represented in the middle of the cylinder, and as the lower steam valve and upper eduction valve are open, the piston must be ascending; and as the crank is connected with the opposite end of the walking beam (or lever), the crank will be descending. By the time that the piston has reached the top, and the crank the bottom, the rocking shaft will be in that position where the pallets upon it are horizontal, and, of course, all the valves will be shut. But the momentum of the paddle (or fly) wheel carries on the motion, and immediately the two valves that were formerly shut, *viz.* the upper steam valve and lower eduction valve, are opened, and the steam presses down the piston with a force equal to the difference between its own elasticity and the elasticity of the uncondensed vapours below the piston. Thus the engines will continue to go, and the paddle-wheel to turn, in the direction of the dart.

"But that we may endeavour to explain to you the

method of stopping or reversing the motion of the paddle-wheel, all that is necessary is to shut all the valves; and this is effected by disengaging the eccentric rod from the spanner of the rocking shaft, and the valves all shut of their own accord, by the weight of the valves, lifter rods, &c., and the engine will stand; and to set the engine a-going, either the one way or the other, is to lower the eccentric rod, to take hold of the double-ended spanner on the end of the rocking shaft, as represented on the sketch, and then the paddle-wheel will move in the direction of the dart, or lift the eccentric rod to the top of the spanner on the rocking shaft, and then the paddle-wheel will move in the opposite direction. The use of the sector-formed appendages T, on the end of the eccentric rod, is to conduct the pins on the ends of the double-ended spanner into the notches adapted for them on each side of the eccentric rod.

"The hand-gearing, for starting or stopping the engines, is situated upon the deck of the boat, and all concentrated upon the top of a small table, in view and in hearing of the man at the helm, or the master, who directs both, when coming to the quay.

"1, a double-ended handle, which is upon the upright shaft 2, on the lower end of which is a bevel wheel 3, working into another wheel 4; this wheel is on a lying shaft, which extends from the one engine to the other, and carries on each end of it a spur pinion 5, which pinion works into the rack 6. There is a similar rack connected with the eccentric rod of the other engine, into which the other spur pinion works; so that, by turning the handle 1, both engines can be started, stopped, or reversed, with the greatest facility and certainty that could be wished for. These bevel wheels, spur pinions, and racks, must be so proportioned to one another, as that two complete turns of the handle 1, will raise the eccentric rod from the lowest to the highest position. One turn of the handle raises or lowers the eccentric rods into the stopping position; and one turn, either the one way or the other, as circumstances require it, sets the boat a-head or a-stern.

There is a projecting piece 7, fixed upon the upright shaft, which catches into a notch, pressed by a spring, which supports the racks and eccentric rods, at any of the three positions that may be required.

"As the said upright shaft makes two turns, and always stops at the same point, it is not suitable for the index. To remedy this, there is a small pinion 8, below the table, working into a wheel 9, with four times the number of teeth, for carrying the index 10. This wheel, making but half a revolution for two revolutions of the upright shaft, makes the index upon its arbour stand fore and aft when the engines are going, and thwart ships when the eccentric rods are set in the standing position.

"The index 11, is connected with the regulating valve 12, by rods and spanners, and turned by hand, as circumstances require.

"The index 13, is connected with the injection cock by rods and spanners, it being always shut before the engines are stopped, and opened when the engines are started. Each engine has separate gearing for the regulating valves and injection cocks, and graduated circles on brass plates, to show, by inspection, the position in which they are standing.

"When the engines stand for some time, it is necessary to let the steam pass freely through them for two or three seconds, on purpose to heat them, and expel any air that may have got inside. For this purpose, the long handle 14, standing by the side of the table, is fixed to a shaft 15, which goes across the front of both engines, and by four short spanners (or pallets) upon it, lifts all the valves of both engines, and allows the steam to pass freely through them by the air-pump valves. The engineer knows by the sound when to replace the handle in the position shown in the sketch; and having previously set the index for the head or stern motion in the direction wanted, and adjusted the steam-regulating index, the last thing he has got to do is to open the injection-cocks, and immediately the engines start in the direction wanted.'

Internal Arrangement of Steam Vessels.

We conclude this section by a representation and concise description of the interior arrangement of steam boats, as they have been generally constructed; the machinery introduced is of the ordinary kind, and will, therefore, not require a particular explanation.

The upper figure represents a longitudinal and vertical section, from stem to stern, of a steam vessel; and the lower figure, a plan of the same, with the deck removed; similar letters in each figure refer to corresponding parts.

a a are two boilers; *b* the chimney, leading from the flues of both the fires; *c* is the steam pipe, only partly brought into view in the section, but its course is better seen in the plan, where it is shown to proceed from both the boilers into a single tube, which conveys it into another cross tube, that connects it to the two cylinders *d d*, by the intervention of the valve boxes *f f*. The air-pumps *e e*, are worked by the main beam, and the eccentric, for giving motion to the valves, is shown at *g*. The paddle wheels *h h*, are usually attached to the main crank by a coupling-box, or toothed-wheels, which enables the engineer to throw off either of the propelling wheels at pleasure; *i*, one of the paddle-boxes, seen only in the section. *j* is the fore-cabin, *k* the after-cabin, *o o* are stair-cases; *l l l l* the framing of timber which supports a platform or deck (commonly called the gangway), which nearly surrounds the hull of the vessel.

Section and Plan of a Steam Boat.

SECTION V.

LOCOMOTIVE STEAM CARRIAGES.

The first part of this work concludes with Mr. Galloway's observations on this important subject, in which he refers the reader, for the description of several carriages, to the Register of Arts, and Journal of Patent Inventions; the author of the Appendix has, therefore, thought it advisable to save the reader the trouble of reference, by introducing an account of those machines in this part of the work, together with such others as have lately been invented; and thus include in one volume, all that has hitherto been done or attempted, worthy of notice, in this highly-interesting and perhaps feasible project. The difficulties to be surmounted are unquestionably great, but, it is hoped, not insuperable. Had the many ingenious men, who are now actively engaged in constructing steam *coaches*, been contented with attempting the formation of steam *waggons*, it is probable that complete success would ere now have crowned their labours. Improved combinations and simplifications of the machinery would have been gradually introduced, tending to reduce the friction, increase the power, and accelerate the speed; but by attempting so much at once, the chances of failure are multiplied, and the success of an undertaking apparently easy in accomplishment, when proceeded upon step by step, is endangered.

Patent Steam Carriage, by Julius Griffith, of Brompton, Middlesex. 1821.

This was, we believe, the earliest attempt made in England *to construct* a locomotive steam-coach, to travel on the common road. Although the experiments that were made with it proved unsuccessful, several of its mecha-

nical combinations have afforded useful hints, which have not been overlooked by succeeding mechanicians in similar undertakings.

The body of the carriage was adapted to carry either goods or passengers; it was guided by means of a lever operating upon the fore wheels of the carriage, so as to turn them round horizontally upon the ground, or to place them in an oblique position to make curves in the road. The yokes which carried the fore wheels were not connected to the main perch of the carriage, but to a short revolving perch. This perch was embraced at each end by an iron hoop, the one being fixed to the main perch, the other to the framing of the yokes; so that when the carriage passed over inequalities in the road, the carriage would oscillate upon the revolving perch, and preserve its erect position.

Two upright steam cylinders, with their piston rods working a crank at right angles to each other, were employed as the propelling power; these, with their furnace, boiler, condenser, and other appendages, were situated in the hind part of the carriage; and, to prevent them from partaking of the concussions and other irregular motions of the carriage, they were fixed upon a swinging platform, suspended to an elevated iron frame-work; and elasticity was given to the chains by the introduction of strong heliacal springs.

The boiler consisted of a series of metal pipes, into which water was forced by a pump from a reservoir. The steam from the engine was condensed in a series of flat pipes exposed to the cooling influence of the atmosphere, from whence the water ran into the reservoir again.

The power of the engine was communicated to the hind heels by means of "sweep rods," at the lower parts of which were pinions and detents taking into toothed wheels; which toothed wheels, being fixed to the hind unning wheels of the carriage, communicated their motion, and impelled the vehicle.

Patent Steam Coach, by Messrs. Burstall and Hill, of London and Edinburgh. 1824.

This was the second attempt actually put in execution to propel a coach by steam. Numerous experiments were made with it in London, at various times, the intervals being occupied in making a variety of alterations. The utmost speed attained was, we believe, from three to four miles per hour, which was performed in an enclosed piece of ground. A great deal of time was lost, and expense incurred by the repeated failure of the boilers. The following account of this machine is extracted from the Edinburgh Journal of Science.

"A, represents the boiler, which is formed of a stout cast-iron, or other suitable metal flue, inclosed in a wrought-iron or copper case, as seen in section, where A is the place for fuel, and *a a a* are parts of the flue, as seen in section, the top being formed into a number of shallow trays or receptacles for containing a small quantity of water in a state of being converted into steam, which is admitted from the reservoir by a small pipe. B is the chimney, arising from the centre flue; at D are the two cylinders, one behind the other, which are fitted up with pistons and valves, or cocks, in the usual way, for the alternate action of steam above and below the pistons. The boiler being suspended on springs, the steam is conveyed from it to the engines through the heliacal pipe *c*, which has that form given to it, to allow the vibration of the boiler, without injury to the steam joints. E is the cistern containing water for one stage, say 50 to 80 gallons, and is made of strong copper, and air-tight, to sustain a pressure of about 60 pounds to the square inch. At *e* is one or more air-pumps, which are worked by the beams F E, of the engines, and are used to force air into the water vessel, that its pressure may drive out, by a convenient pipe, the water into the boiler, at such times and in such quantities as may be wanted. The two beams are connected at one end with the piston rods, and at the other with the rocking standards, H H. At about one-fourth of the length of the beams from the piston rods, are the two connecting rods, *g g*, their lower ends being attached to two cranks, formed at angles of 90° from each other on the hind axle, giving,

by the action of the steam, a continued rotatory motion to the wheels, without the necessity of a fly wheel. The four coach-wheels are attached to the axles nearly as in common coaches, except that there is a ratchet wheel formed upon the back part of the nave, with a box wedged into the axle, containing a dog or pall, with a spring on the back of it, for the purpose of causing the wheels to be impelled when the axle revolves, and at the same time allowing the outer wheel, when the carriage describes a curve, to travel faster than the inner one, and still be ready to receive the impulse of the engine, as soon as it comes to a straight course.

"The patentees have another method of performing the same operation, with the further advantage of backing the coach when the engines are backed. In this plan, the naves are cast with a recess in the middle, in which is a double bevel clutch, the inside of the nave being formed to correspond. The clutches are simultaneously acted upon by connecting levers and springs, and which, according as they are forced to the right or left, will enable the carriage to be moved forward or backward. To the fore naves are fixed two cylindrical metal rings, round which are two friction bands, to be tightened by a lever convenient for the foot of the conductor, and which will readily retard or stop the coach when descending hills. K is the seat of the conductor, with the steering wheel, L, in the front, which is fastened on the small upright shaft I, and turns the two bevel pinions 2, and the shaft 3, with its small pinion 4, which, working into a rack on the segment of a circle on the fore carriage, gives full power to place the two axles at any angle necessary for causing the carriage to turn on the road, the centre of motion being the perch-pin I.

"The fore and hind carriage are connected together by a perch, which is bolted fast at one end by the fork, and at the other end is screwed by two collars, which permit the fore and hind weels to adapt themselves to the curve of the road.

"To ascend steep parts of the road, and particularly when the carriage is used on railways, o' to drag another behind

it, greater friction will be required on the road than the two hind wheels will give, and there is therefore a contrivance to turn all the four wheels. This is done by a pair of mitre wheels 4, one being on the hind axle, and the other on the longitudinal shaft 6, on which shaft is a universal joint, directly under the perch-pin I, at 7. This enables the small shaft 7, to be turned, though the carriage should be on the lock. On one end of the shaft 7, is one of a pair of bevel wheels, the other being on the fore axle, which wheels are in the same proportion to one another, as the fore and hind wheels of the carriage are, and this causes their circumference to move on the ground at the same speed.

"The patentees, by a peculiar construction of a boiler, intend to make it a store of caloric; they propose to heat it from 250 to 600 or 800 degrees of Fahrenheit, and by keeping the water in a separate vessel, and only applying it to the boiler when steam is wanted, they hope to accomplish that great desideratum in the application of steam to common roads, of making just such a quantity of steam as is wanted; so that, when going down hill, where the gravitating force will be enough to impel the carriage, all the steam and heat may be saved, to be accumulating and given out again at the first hill or bad piece of road, when, more being wanted, more will be expended.

"The engines are what are called high-pressure, and capable of working to ten-horse power, and the steam is purposed to be let off into an intermediate vessel, that the sound emitted may be regulated by one or more cocks.

"From the foregoing description we think we are warranted in saying, that there is a considerable degree of ingenuity, as well as originality, in many of the details, and also in the general arrangement of the machinery. In this light we regard their mode of allowing the several wheels to move simultaneously at different velocities, the convoluted form given to the steam and water pipes, by which the injurious effects of jolting are avoided by very simple means, and the mode of injecting water into the boiler, by means of compressed air

"By the recent improvements, the boiler is to be placed upon an additional pair of wheels, so that the whole machine may run upon six wheels instead of four. The patentees claim two distinct modes of employing this extra pair of wheels, either of which may be adopted. By the first mode, the back end of the boiler is bolted to the axletree of the extra wheels, and the front end rests and turns upon a pivot, fixed to the axle of the middle pair of wheels. By the second mode, the axle of the hind wheels turns upon a centre, and the boiler is attached to a frame, which encompasses it: this frame is suspended upon springs or not, (according to the nature of the road,) the fore part of it being bolted to the axle of the middle pair of wheels. By either of these contrivances, the carriage containing the boiler may be made to adapt itself to the bends in the road, without incurring injurious strains.

"The next improvement of material importance, consists in the construction of the steam pipes, which have sliding and moveable knee-formed joints, to admit of their extension or contraction, when the carriage is passing over rough or undulating ground; thus constructed, the pipes also accommodate themselves to bends and irregularities in the road.

"The third improvement relates to the mode of steering the carriage, which is effected by a chain circumscribing the steering wheel, the ends of the chain then passing round pulleys fixed on the carriage frame, are attached to the opposite extremities of the fore axletree."

An improved modification of this machine has been since constructed by Mr. Hill, in London; we saw the carriage in the progress of building, but what advantages have resulted from the alterations made, we have not heard; the undertaking has however been lately suspended by Mr. Hill in London, while his partner Mr. Burstall, of Edinburgh, has continued to prosecute it, as will be seen by the annexed account.

Patent Steam Carriage, by Mr. Burstall, Edinburgh. 1827

The above cut is a representation of the model of a coach, constructed in Edinburgh by Mr. Burstall, from the designs, it is said, of Mr. Hill, upon a scale of three inches to the foot, or one-fourth linear measure of the full-sized machine. As this proportion is accurately preserved in all its parts, the model exhibits a faithful representation of the carriage to be used on the road, (if successful) and thus

affords a measure (though not a very correct one) of its performance.

The coach is exactly of the common form, and carries six inside and twelve outside passengers, but it has an additional pair of wheels behind, for supporting the boiler. The length of the model is five and a half feet, its height twenty-two inches; the length of the full-sized coach, with its engine, will be twenty-two feet, its height seven feet four inches. The steersman or driver sits in front, and, by turning a circular horizontal plate *c*, gives the first pair of wheels a direction to the right or the left, as in a common coach, when the bends of the road require it. The boiler *b* is supported by an iron frame, extending from the second to the third pair of wheels. It is shaped like a bee-hive or cone, and will be about four and a half feet high in the full machine, exclusive of the chimney. The fire is in the middle, and the water and steam outside. The engine is on the high-pressure principle; and the boiler, which is of copper, is made strong enough to bear a pressure of three hundred pounds on the inch, though it is intended to work with only twenty-five pounds. Two cylinders are employed; they occupy the hind boot, and rest on the axle of the middle wheels; in the model, the cylinders are three inches in diameter, with a stroke of three inches. The cistern *a* is below. The engine pumps up water for itself, which passes from the cistern by a pipe; another pipe *e* conveys the steam to the cylinder; a third pipe *i* carries off the waste steam from the cylinders into the chimney, from which, being expanded by the heat, it escapes invisibly. The engine, when worked with steam of twenty-five pounds, will be of ten-horse power in the full-sized carriage; and the whole weight of the engine and carriage, with the charge of fuel and water, will be about three tons.

This model of the carriage was exhibited at work in Edinburgh (and other places), where it travelled round a circle of seventeen feet in diameter, on an uneven deal floor, with a speed equal to seven or eight miles per hour. A deal platform, 18 feet long, rising 1 foot at the end (or 1 in 18), was fixed, which the carriage ran up with ease and

rapidity. On the outside of the circle was a deal bank, which rose 5 in 25 in the cross section, to show how little laying on one side would affect her safety, owing to the centre of gravity being placed so near to the ground. The carriage was subjected to the roughest usage, by running her over tools of various kinds laid in her way, and it was asserted that this model run, in the space of eight days, 250 miles, without any fresh packing or repair.

Patent Steam Carriage Machinery, by W. H. James, of Thavies Inn, Holborn. 1824.

Instead of actuating the several wheels of a carriage with a single engine, as heretofore, Mr. James adapts separate engines to each wheel. These engines are of small and equal dimensions, and have their steam supplied with pipes connected with the boiler, situated in a convenient part of the carriage. The object of the patentee in employing separate engines is, that each wheel may have a motion independent of any of the other wheels, so that their powers or velocities may be varied at pleasure, which is essential in passing round curves, or turning corners of the road; because (as is well understood) when a carriage moves in the arc of a circle, the outer wheel moves over a greater space of ground than the inner wheel, consequently rendering it necessary that the engine connected with the outer wheel should be made to work so much faster than the engine connected with the inner wheel. This, Mr. James effects by a very simple contrivance; he causes the fore axletree to be connected with a stop-cock placed in the main pipe, through which the steam passes from the boiler to the respective engines; this stop-cock is so constructed, that when the fore axletree stands at right angles to the perch, (*i. e.* when the carriage is proceeding in a straight line,) it admits equal quantities of steam to each engine; but whenever the axletree stands obliquely to the perch, (as in making curves in the road,) it causes the stop-cock to admit a greater quantity of steam to the engine connected with the outer wheel, so as to cause that wheel to revolve faster, and a diminished quantity to

the engine connected with the inner wheel, so as to make it revolve slower, in exact proportion to the curve around which the carriage is moving.

Upon roads of moderate elevation, Mr. James applies separate engines to each of the hind wheels only; but upon roads that have greater ascents, he employs four engines, that is, one to each wheel; and thus he obtains a greater degree of resistance or friction upon the surface passed over. In ordinary roads, however, Mr. James considers that two engines will be sufficient, because it is not required, *on this principle*, that the wheels shall be thrown out of gear, and in passing round curves they may be kept constantly in action; thus the amount of friction against the road will be preserved tolerably uniform, which is of course very important in propelling a carriage in the precise line required; if, under any circumstance, as in passing down hills, it may be advisable to lock one of the hind wheels, it may be performed as in other carriages, by putting on a drag.

From what we have already said, we think the advantages resulting from the employment of a separate engine to each wheel must be apparent. The next consideration was, to give each wheel an independent rotatory motion, without the necessity of employing fly-wheels; this Mr. James produces by having two small cylinders to each engine, as shown in fig. 1, (which we shall presently describe). Without such an arrangement, in passing over rough or loose ground, or in the ascending of steep hills, the impulse given to the carriage would frequently not be sufficient to carry the engines over their centres.

The next object,—which has been considered as one of almost insurmountable difficulty, that of putting the whole of the machinery upon springs, so as to prevent any injurious consequences to the acting parts from concussions, and likewise, at the same time, to allow of the perfect and uniform operation of the engines upon the running wheels, when passing over rugged surfaces,—Mr. James effects by causing the engines and their frame-work to vibrate altogether upon the crank-shafts, as a centre; at the same time connecting these engines to the boiler and exit passages, by means of hollow axles moving in stuffing-boxes, which, together with the body of the car-

riage, is suspended upon the springs; these springs rest upon the axletrees, as will be understood by an attentive examination of the figures, (especially fig. 3,) which we shall now proceed to explain.

Fig. 1, is a plan of the machinery of a carriage, as applied to the hind wheels. Fig. 2, is a cross section, giving an end view of the boiler and the cranks, showing the manner in which the former is suspended, its mode of attachment to the body of the carriage, and the situation of the springs on which it rests. Fig. 3, is a longitudinal section, giving a side view of the machinery as attached to the running wheels; similar letters of reference apply to the corresponding parts in each of the figures.

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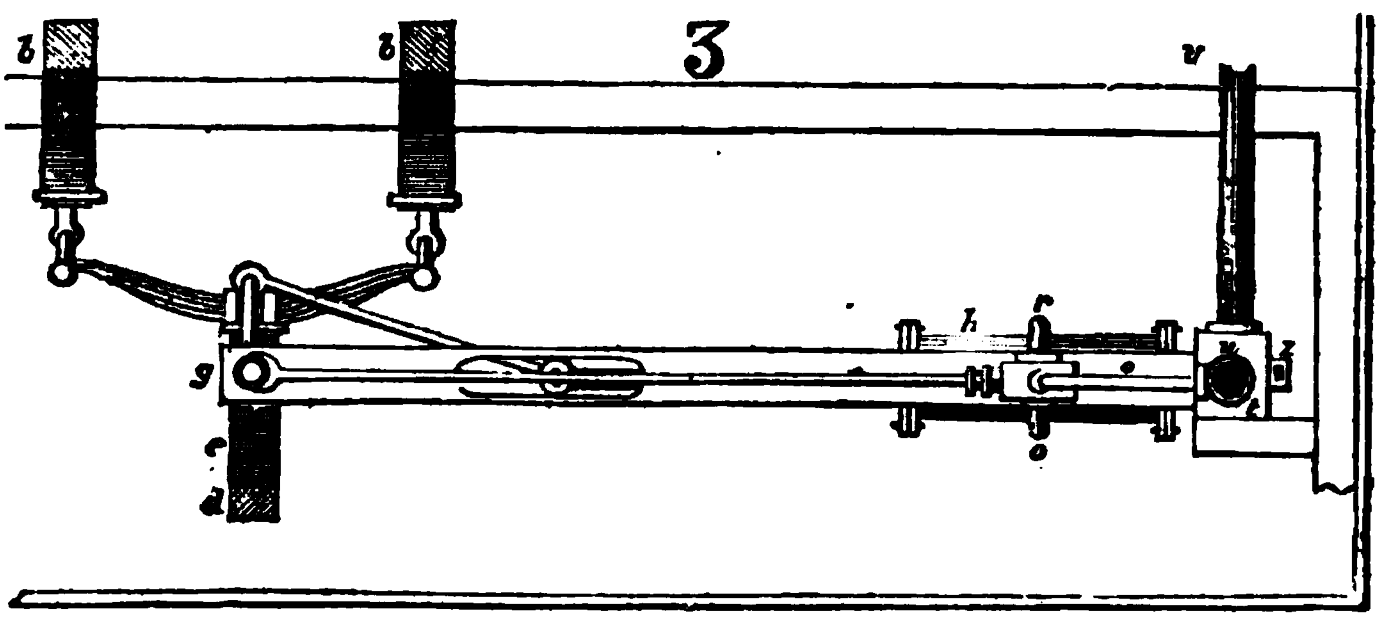


Fig. 1, *a a* represent the boiler suspended to the framework *b b b b* above, which frame-work is firmly attached to the body of the carriage *c c c c*, and forms its support; *d d* the axletree, the form of which is best seen in fig. 2, has four supports *e e e e*; the axles of the running wheels *f f*, are fixed thereto, and are connected, in one piece, with each of the crank shafts *g g*; by which each of the wheels is made to revolve independently of the others. Each of the engines has two cylinders *h h*, which operate by their piston rods upon the cranks; to these separate engines, steam is supplied from the boiler *a a*, by means of the pipe *k*, which enters at the stop-cock *b*, into the steam box *m*; from this box the steam passes into the pipes *n n*, which move steam-tight through stuffing boxes; from thence the steam proceeds through the pipes *o o o*, to

the slide boxes *p p p p*, the slides being worked by eccentrics *q q q q*, on the crank-shafts, in the usual manner, and from thence to the cylinders. The exhaustion pipes *r r*, lead into the hollow axles *n n*, before described, in which there are partitions *s s*, to separate the steam from the exit passages, which pass through the said hollow axles to the boxes *t t*; from which there are pipes *u u*, leading into the chimney *v*, shown in section. The rods *x x*, are attached to the fore axle of the running wheels, and also to the two handles of the cock *l*, so that the fore axle and the cock move simultaneously, and parallel to each other. *z z* represent part of the frame-work extended, for tying the engines together by means of a connecting bolt; and so as to allow the body of the carriage to have a slight lateral motion upon its springs, independently of the engines, by means of the hollow axles sliding longitudinally through the stuffing-boxes.

In the preceding account, we have given the substance of Mr. James's specification; and, although it contains much novel and valuable matter, he limits his claim of patent-right to the following points only, which we add verbatim:—

"I have herein described, for the perfect understanding of my invention, the general construction and operation of a steam carriage to be actuated upon my improved principles; but I do not mean to confine myself to this particular construction or adaptation of parts, as my invention consists simply and exclusively in adapting distinct steam engines to the several wheels upon which the carriage runs, for the purpose of actuating such several wheels independently of each other, whatever may be the number of wheels so employed, or whatever may be the construction or position of the steam engines and their appendages so adapted, or whatever may be the form of the carriage to be propelled."

We shall have occasion further on to give an account of some experiments made with carriages on this construction, in the order of their date.

Patent Steam Carriage, by Mr. Goldsworthy Gurney, of Argyle Street, London. 1826.

Mr. Gurney has done more in experimental trials than any other individual, owing probably to his having had greater funds placed at his disposal; it must also be admitted,

that he has succeeded in making more extended journeys at the speed of ordinary stage coaches than his contemporaries. There is, however, nothing new in his mode of propelling, and that degree of success which has attended his efforts, we rather attribute to his application of the light tubular boiler, described at page 395. The annexed popular description of the construction of the carriage represented in the preceding page, is extracted from a weekly periodical, with some slight curtailments.

The carriage is constructed for accommodating six inside and fifteen outside passengers, independently of the guide, who is also the engineer. In front of the coach is a very capacious boot, while behind, that which assumes the appearance of a boot, is the case for the boiler and the furnace, from which no inconvenience is experienced by the outside passenger, although, in cold weather, a certain degree of heat may be obtained, if required. The

length of the vehicle, from end to end, is fifteen feet, and with the pole and pilot wheels, twenty feet. The diameter of the hind wheels is five feet; of the front wheels, three feet nine inches; and of the pilot wheels, three feet. There is a treble perch, by which the machinery is supported, and beneath which two propellers, in going up a hill, may be set in motion, somewhat similar to the action of a horse's legs under similar circumstances, which assist in forcing the carriage to the summit.

In descending a hill, there is a break fixed on the hind wheel, to increase the friction; but, independently of this, the guide has the power of lessening the force of the steam to any extent, by means of the lever at his right hand, which operates upon the *throttle valve*, and by which he may stop the action of the steam altogether, and effect a counter vacuum in the cylinders. By this means also he regulates the rate of progress on the road. There is another lever by which he can stop the vehicle *instanter*, and in a moment reverse the motion of the wheels, so as to prevent accident, as is the practice with the paddles of steam vessels. The duty of the guide, who sits in front, is to keep the vehicle in its proper course, which he does by means of the pilot wheels acting upon the pole.

The total weight of the carriage and all its apparatus is estimated at one and a half tons, and its wear and tear of the road, as compared with a carriage drawn by four horses, as one is to six. The engine has a twelve-horse power, but may be increased to sixteen; the actual power in use, except in ascending a hill, is eight horses.

Fig. 1, gives a side view of the machine; *a*, the guide and engineer, to whom the whole management of the machinery and conduct of the carriage is entrusted. Besides this man, a guard will be employed, whose duty it will be to look after the luggage and passengers; *b*, the handle, which guides the pole and pilot wheels; *c*, the pilot wheels; *d*, the pole; *e*, the fore boot, for luggage; *f*, the throttle valve of the main steam pipe, which, by means of the handle, is opened or closed at pleasure, the power of the steam and the progress of the carriage being thereby

regulated, from one to ten or twenty miles per hour; *g*, the tank for water, running from end to end, and the full breadth of the carriage; it will contain sixty gallons of water; *h*, the carriage, painted claret colour, and lined with cloth of the same hue, capable of holding six inside and twelve outside passengers; *i*, the hind boot, containing the boiler and furnace; it is encased with sheet iron, and between the pipes the coke and charcoal are put, the front being closed in the ordinary way (as seen in fig. 2.) with an iron door. The pipes extend from the cylindrical reservoir of water at the bottom, to the cylindrical chamber for steam at the top, forming a succession of lines something like a horse-shoe, turned edgeways. The steam enters the "separators" through large pipes, and is thence conducted to its proper destination; *k k*, separators, in which the steam is separated from the water, the water descending and returning to the boiler, while the steam ascends, and is forced into the steam pipes of the engine; *l*, the pump, by which the water is pumped from the tank, by means of a flexible hose, to the reservoir communicating with the boiler; *m*, the main steam pipe descending from the "separators," and proceeding in a direct line under the body of the coach to the "throttle valve," and thence, under the tank, to the cylinders; *n n*, flues of the furnace, four in number; *o*, the perches, of which there are three, conjoined, to support the machinery; *p*, the cylinders, there is one between each perch; *q*, valve motion, admitting steam alternately to each side of the pistons; *r*, cranks operating on the axle, are crotches which, as the axle turns round, catch projecting pieces of iron on the boxes of the wheels, and give them the rotary motion—the hind wheels only are thus operated upon; *s*, propellers, used as the carriage ascends a hill; *t*, the drag, which is applied to increase the friction on the wheel in going down a hill; this is also assisted by diminishing the pressure of the steam, or, if necessary, inverting the motion of the wheels; *u*, the clutch, by which the wheel is sent round; *v*, the safety valve, which regulates the proper pressure of the steam in the pipe; *w*, the orifice for filling the tank; this is done

by means of a flexible hose and a funnel, and occupies but a few seconds.

Fig. 2, exhibits a back view of the carriage, and the perches that support the machinery, not here introduced; *a*, the furnace door; *c*, guage cock; *d*, blow cock; *e e*, steam pipes; *f f*, flues to furnace; *g g*, the pipes through which the water is propelled from the separators *h h*, into the boiler.

Patent Steam Coach, by the late Mr. David Gordon.

Although this carriage was not actually built until after Mr. Gurney's, described in the last article, it is proper to notice that the peculiar mode of propelling herein adopted was patented by Mr. Gordon, seventeen months prior to Mr. Gurney's patent. Six months after the sealing of Mr. Gordon's patent, a description and drawing of it was published in the Register of Arts; after that time, the patentee's avocations prevented him from constructing the machine here represented, which is an improved modification of the former carriage. The alterations chiefly consist in placing the propellers in the fore part of the carriage instead of behind it; in raising them from the ground by means of a light revolving crank, (having six throws, that being the number of propellers employed,) which effects the operation with greater regularity, and by much simpler arrangements than by the eccentrics previously used. The machinery, generally, is also much simplified. Instead of the former caravan-shaped vehicle, there are to be accommodations for the outside passengers, similar to those in our ordinary stage coaches; but the inside passengers are to sit in a row facing the fore part, in an apartment much resembling that in front of a French *diligence*, similar to the design in the preceding page.

The carriage runs upon only three wheels, one in front, and two behind, and each of them have a separate axle. The latter circumstance affords a great advantage in the hind part of the carriage, where the two wheels are opposite to each other; there being no cross-axle, an increased capacity is obtained in the body of the carriage, exceedingly useful in the stowing of heavy goods in ordinary cases; but as now employed for locomotion by steam, of great convenience, as a depository for fuel and water. The wheels roll *perpendicularly* on their axes, between strong parallel bars, which become the bearings of the axes; a considerable degree of friction is thus avoided; while the single wheel in front gives a greater facility of turning, and in a less space, than coaches having two fore wheels. This peculiar construction of the body of a carriage is a

distinct patent of Mr. Gordon, antecedent to that for the propelling apparatus now under consideration.

The engines and other machinery rest entirely upon the springs of the carriage, to preserve them from the injurious effects of the concussions made by the wheels upon loose stones or other obstacles lying on the surface of the road.

In the body of the carriage, connected with the piston rods of the engine, is a six-throw crank; to these throws or arms are attached the propellers, which by the revolution of the crank are successively forced out against the ground in a backward direction, then drawn up again, precisely in the manner of the hind legs of a horse. The rods are formed of iron tubes filled with wood, to combine lightness with great strength. To the ends of these rods are attached what may be considered as substitutes for horses' feet, although their form, being the segments of circles, is very different. They press against the ground by a rolling kind of motion, causing a sufficient adhesion to the surface without digging it up, and adapt themselves to any turn of the carriage. The under part of these feet is formed into short strong brushes, supported by iron teeth, that the latter might take effect, in the event of the other part failing.

In going down a hill, these propellers are lifted off the ground by the guide at pleasure, so that the carriage proceeds entirely by its own gravity; if the descent should be steep, or the motion too rapid, the guide then makes use of a break, by which the motion can be retarded, or entirely stopped. If the carriage be proceeding upon a level, the lifting of the propellers alone stops the carriage gradually, but quickly, if ascending an inclined plane. This application of the propellers affords also a very facile means of making a turn in the road, simply by lifting them on one side, and allowing them to act on the other, which is done by the mere pulling of a cord; the guide has also the power of producing the same effect by turning a lever in front of him, which, by means of a

pinion, operates upon a toothed sector on the circular frame that surrounds the front wheel; either of these modes may be employed, or both of them in conjunction; thus very great facilities are afforded, for making quick and sudden turns in the road.

In countries where sledges are used, for travelling over snow, the machine may be placed upon skates, and the feet of the propellers be shod with suitable iron teeth.

The preceding engraving represents a side elevation of the machine. *a*, the end of the boiler; *b*, the flue; *c*, an apartment for the engineer to attend the fire, and regulate the machinery, which apartment contains a store of water, coke, &c.; *d*, external connecting rod (on each side of the carriage) that unites the driving cranks of the propellers to the small lifting cranks within the carriage; *e*, being the axis of the driving cranks; and *f*, the axis of the lifting cranks; *g*, the apartment for the inside passengers, which has glazed windows in front; *h*, the seats for the outside passengers; *i*, the conductor, who guides the carriage by means of four cross levers, turning a small pinion of seven teeth, that work in a toothed sector, fixed on the periphery of the circular frame; *p p*, propellers, of which the whole six are brought into view; *s s*, the straps or ropes by which the propellers are successively lifted from the ground.

Having given a general description of the carriage from its external appearance, we proceed to explain the internal machinery by which the propulsion is effected.

In the fore part of the carriage, and centrically between the driving and lifting cranks of the propellers, are placed the steam engines; these consist of two brass cylinders, in a horizontal position, which vibrate upon trunnions; and the latter being hollow, form the induction and eduction passages for the steam. The piston rods of the cylinders are attached to two distinct throws of the driving crank, placed at right angles with respect to each other, so that the vibrations of the cylinders admit of the piston rods following the revolution of the crank. Thus there are eight throws to the driving crank; *viz.* two for the cylinders, and six

(FIG. 2.)

for the propellers, turning upon the same axis, but upon nine distinct bearings (two to each throw) on the frame work of the carriage. The force of the steam engines, and the rotary motion of the driving crank are communicated to the lifting crank by means of connecting rods, on the outside of the carriage (as exhibited in the elevation of the machine in our last number, and by the subjoined plan fig. 2); and the arrangement is such, that the throws of each respective crank are always parallel to each other.

Reference to fig. 2.—This diagram represents a plan of the machinery in the fore part of the carriage; *kk*, are the eight throws of the driving crank, the axis of which turns in plummer blocks fixed on the wooden frame of the carriage; *b b*, the six throws of the lifting crank, the extremities of whose axis are connected to the ends of the axis of the driving crank by means of the rods *d d*. *p p*, are the feet of the propellers, connected by their rods *o o*, to the driving crank; and *s s*, are the double straps by which the feet of the propellers are attached to the lifting crank. The steam is brought on from the boiler (situated at the back part of the carriage) by the pipe *r r*, and passing through a breeches piece enters the cylinder *n n*, by the hollow trunnions *t t*, on which they vibrate; the steam passes out of each cylinder through the opposite trunnions, and escapes by the pipe *v*, to the condenser. The external diameter of each cylinder is five inches. The boiler used in this carriage is one of Mr. Gurney's patent construction.

It will be perceived that there are three throws to the driving crank on each side of the carriage; on one side they radiate from the axis at 120 degrees apart; they are the same on the opposite side, but so posited as to come intermediate with the throws of the former; that is, when the crank is viewed end-ways, all the six throws appear uniformly at *sixty* degrees apart. This arrangement is essential to the proper action of the propellers, which is, that when a propeller on one side has been thrust out, another propeller on the opposite side shall succeed its movement, instead of an adjoining one. The action of these propellers, which we have seen, is very beautiful; a more uniform and perfect movement cannot well be devised by simpler means. The annexed diagram, fig. 3, will afford a clear idea of their action.

The large crank on the left shews, at 1, 3, 5, the three throws of the driving crank on one side of the carriage; and the small crank on the right, the same of the lifting crank; the respective throws of each crank are parallel, and they continue so by revolving together; the figures 2, 4, 6, in-

(FIG. 3.)

termediate between the throws of each crank, mark the situation of these throws on the opposite side of the carriage. It will now be seen that the propeller marked 1, is, by the position of the crank, being just lifted from the ground, while that marked 2, (which is on the opposite side) would, had it been drawn in, be just commencing its operation; then 3 on this side, falls into the position of 2 and 1; then 4 on the other side follows, and in like manner, 5 and 6. Thus by the revolution of the cranks, the feet of the propellers are made to describe an ellipsis; they first touch at the heel, and by their curved figure roll round to the toe, (as the carriage is thrust forward) when they are drawn up; although this must be their motion, it could not be perceived when a carriage was moving rapidly; they would appear just to touch the ground, at considerably greater distances than the actual space between the propellers, owing to the impulse given to the carriage, by each successive push.

It has been stated, that if one of these propellers were to be forced against the perpendicular side of a stone firmly imbedded in the road, a breakage of the propeller must be the result; but it appears to us, that if the propellers are as strong as their construction would lead us to

suppose they are, the only effect of such a circumstance would be to give the carriage an increased impetus.

The power required to give motion to a carriage, is in proportion to the force of gravitation which keeps it at rest. When, however, that force is overcome, the momentum given would be continued, but for the friction and the resistance of the bodies moved through. This will account for the rapid travelling of our ordinary stage-coaches; the momentum having been given, the force requisite to continue their motion is comparatively small. In Mr. Gordon's locomotive carriage, the impulse is given under nearly similar circumstances to those of stage-coaches drawn by horses; consequently, the effect will be nearly the same. A carriage was constructed on the aforesaid plan, and some experiments made with it, which, though not so successful as was expected, proved the feasibility of the project; the steam power provided was found inadequate to produce the required velocity of motion.

Patent Steam Carriage, by Mr. Goldsworthy Gurney, of Argyle Street. 1828.

The following is a description of Mr. Gurney's more recent combinations, which have formed the subject of a second patent, in 1828. The new carriage differs but little from the former one in its external appearance; by a reference to the description of which, whilst perusing the subjoined account of the new arrangements, the reader will be able to form a correct idea of the whole. The principal novelties are the following:—

The coachman, or conductor, occupies the front seat over the fore-boot of the carriage, the lower seat being removed. The four chimneys of the former carriage are substituted for a single one of great width. The water-tank, instead of being above the perch, and extending the whole length of the carriage, is now placed below the perch, and lies between the fore and hind wheels. The propellers are removed entirely. A blowing machine is introduced, for maintaining a sharp draught in the fur-

nace, which is worked by a separate cylinder from those employed in propelling the carriage. A mode of heating the water before it is admitted into the boiler, and an additional force-pump unconnected with the engine, to be worked by hand, to throw in an increased supply of water into the boiler whenever needed, are also adopted.

The coach, in its form and accommodations, bears a close resemblance to the stage-coaches at present in use. It has a fore and hind boot, on which are seats for the passengers, and a box in front for the coachman, with room for a passenger beside him. The body of the carriage is supported upon three parallel perches, extending its whole length; the hinder part hangs upon springs, fixed upon the perches, immediately over the axis of the hind wheels, and the fore part is placed upon iron supports on the perches. The carriage runs upon six wheels, a small pair, called the pilot-wheels, being placed in front for guiding the vehicle; these are connected to the ordinary fore wheels of the carriage by a small curved perch, which admits the axle of the former being placed oblique to the latter, by the turning of a lever, fitted on to the upper extremity of an upright spindle, which is attached to the axletree. The hinder extremity of this small perch is attached to an iron frame supported upon springs, that are fixed on the axletree of the fore wheels; a little before the axletree, a strong pin passes through the small perch and the centre main perch, which serves as a centre of motion to the small perch, so that the pilot-wheels being placed obliquely, the perch turns upon the pin, and the fore wheels of the carriage with it. When not acted upon by the steering lever, the pilot-wheels are maintained at right angles to the perch by means of springs.

The blowing machine is placed, as beforementioned, in the fore boot; it consists of a fly of five vanes, that revolve on a vertical spindle, similar to a winnowing machine, but in a reversed position; this apparatus is worked by a small horizontal steam cylinder placed beneath, on the frame of the carriage. The piston rod of this cylinder is connected to a crank on the axis of a fly-wheel, revolving in a horizontal direction above; and to the same

crank is attached, by an intermediate rod, the plunger of the force-pump, which injects the water into the boiler. The steam engine thus drives the blowing machine and the force-pump, the fly-wheel serving to equalise the motions of both. The connexion between the blowing machine and this steam cylinder is thus arranged: on the vertical axis of the fly-wheel are fixed small band-wheels or pulleys, of different diameters, and on the vertical spindle of the blowing machine are fixed other pulleys, which being connected to the former by an endless band, are driven round with them; the varied sizes of the pulleys enabling the engineer to force the air through the machine with any required rapidity. The air enters the blowing machine at the bottom of the circular box, wherein the vanes revolve, and is forced out at the side into a broad flat tube, called the "air passage," which leads under the body of the coach into the ash-pit of the furnace.

This boiler, which is placed in the hind boot, consists of two or three series of pipes of an inch bore, bent into the form of a horse-shoe, and supporting the fire-grate at their upper and lower extremities, with two horizontal tubes of larger dimensions, into which the open ends of the before-mentioned smaller bent tubes enter and are fixed; and the two large horizontal tubes are connected by a series of ten open vertical pipes. The whole of the bent tubes, the lower straight horizontal tube, and the half of the upper one, (which may be termed a steam reservoir,) are kept filled with water. From the top of the steam chamber proceed two curved pipes, which enter two large vertical tubes of strong plate-iron, strengthened by hoops externally; these last are called *separators;* they communicate at their lower ends with the boiler, and at their upper ends by a connecting tube, from which a branch enters the chimney, and passing over the top and down the back of the furnace, is carried through the air passage, along through the fore boot, and back again, as far as the centre of the carriage, where it is connected with two horizontal cylinders, firmly secured between the main perches, and serving to give motion to two cranks

on the axis of the hind wheels, by which means the carriage is impelled.

The steam is worked expansively, being shut off at half the stroke by means of a slide valve, the rod of which is worked by a cam on the axis of the hind wheels. The slide valves, by which the steam is admitted to the cylinders, are worked by a lever, on the axis of which is fixed an elliptical ring; and to reverse the motion, a line is attached to the rod, and placed within reach of the coachman; by pulling this line, the pin is brought into the upper notch, and the motion of the carriage thereby reversed.

Beneath the main perches is placed the tank, for the supply of the boiler; it communicates (by pipes from its lower part,) with the force-pump beneath the fore boot, and also with a small forcer placed within reach of the fire-man, who sits behind the boilers. Immediately above the tank is a flat vessel, through which the steam passes from the eduction pipe, and thence by another pipe into the chimney.

The pipe from the force-pump passes through the air-chamber, and forming a coil above the horse-shoe tubes, delivers the water into the upper part of the steam chamber. The supply from the pump may be diminished by partially opening a small cock, which allows a portion of water to return to the tank.

Any part of the preceding account that may appear abstruse to the reader, will be rendered perfectly clear by an inspection of the subjoined engraved vertical section of the machine, together with a reference to the following explanatory letters.

a a a, a series of small tubes, in two or more ranges, forming the boiler, the interior range serving to support the fuel; these tubes are connected with *b b*, two larger tubes, the upper one forming a steam chamber; *c*, one of a range of tubes connecting *b b* together; *d*, one of the two separators, connected with *b b* by two curved pipes; *e e e*, steam pipe proceeding from the upper part of the separator, and passing down through the chimney and

Vertical Section of Mr. Gurney's Improved Steam Coach. 1828.

beneath the body of the carriage into the fore boot, whence it descends to *f*, the cylinders which propel the carriage by means of cranks *g*, on the axis of the hind wheels; *h*, an eccentric, which works the slide-valve *i*, by a lever turning on its centre, and to the extremities of which lever an elliptical ring *k*, is attached; *l l*, a line, fastened at one end to an eccentric rod, and at the other end to a short lever in the fore boot, which may be elevated by means of the lever *m*; this raising the eccentric rod, causes the pin in its extremity to act upon the upper side of *k*, and thus *reverses* the motion of the carriage; *n*, lever for regulating the throttle-valve *o*; *p*, eduction pipe, opening into a flat chamber *q*, in which the steam expands, and thence passes through the waste pipe *r r*, into the chimney *s s*; *t*, tank for water; *u*, force-pump, supplied by the suction pipe *v*, and forcing the water through the pipe *x x x*, (which forms a coil above the boilers,) into the tubular boilers *a a a*; *y*, a stop-cock, by which the supply from the force-pump is regulated, any requisite portion being allowed to return into the tank; *z*, seat for the fire-man; 1, a blowing-machine, or frame driven by bands from the axis of the fly-wheel 2, which is worked by a small engine 3, serving also to work the force-pump *u*; 4 4 4, steam pipe, supplying the engine 3; 5 5, air-channel, leading from the blower to the furnace; 6, guide-wheels, which may be placed obliquely to the perch 8, by the lever 7; 9, centre of motion on which the perch 8 turns, thus turning the fore wheels, on the axis of which are springs that support the fore part of the coach; 11, force-pump, to supply the boilers, in case the water is too low to be worked by the fire-man.

Patent Steam Phaeton, by Dr. Harland, of Scarborough. 1828.

The improvements contemplated by Dr. Harland, are stated, in his specification, to consist, first, in the construction of a boiler, by which a very large surface of the fire and flue will be placed in contact with the water, for the

rapid production of steam; secondly, in the employment of a condenser, which, by its extensive surface, shall condense the steam by the influence of the atmosphere; thirdly, in a mode of fixing the working cylinder, without allowing it to vibrate in hollow arms or trunnions.

a a, represents the bed of the carriage; *b* 1 and *b* 2, the boiler, composed of two double cylinders, *b* 1 containing the fire-grate and ash-pit, and the cylinder *b* 2 containing another double cylinder; so that there are, in fact, three double cylinders, each full of water, and communicating with the reservoir and steam chamber *c*, which must be of sufficient capacity to keep the boilers supplied during the period of one stage, and so that they be always full; *d*, is the chimney; *e*, a damper, by which the boiler *b* 2, may occasionally be withdrawn in part from the action of the fire; *f*, is a spherical vessel on the top of the reservoir, the object of which is to prevent the water thrown up with the steam being driven with the steam into the pipe *g*, which conveys it to the working cylinder *h*; this cylinder is secured horizontally to the bed of the carriage, and, having guides extending from end to end, in which side-rods, attached to the cross on the piston rod, move, and carry with them the connecting rod *k*, which turns the crank *l*; this crank has on its axis a toothed-wheel *m*, and revolves on bearings placed on the bed of the carriage. The carriage receives its impulse from the engine upon the hind wheels; the axis of these carry small tooth-wheels *n*, which gearing into *m*, receive their motion and thereby turn round the running wheels. Arrangements are made by the patentee for throwing the toothed-wheels *m* and *n* out of gear, and bringing into operation another pair of wheels on the same axles, when additional power is wanted; but the apparatus for this purpose is not brought into view in the engraving, to prevent confusion. At *o* is an eduction pipe, leading to a series of tubes *p*, which are denominated the condensing chambers, and may be used, either alone or in conjunction with water, to condense the steam on leaving the cylinder; *q*, is a pipe for conducting the hot water and uncondensed steam into

into a globular vessel *r*, connected with an additional series of condensing pipes *s*, of an annular form, and connected with each other by short pipes; *t* is a pipe for returning the condensed water from *r* to the boiler, by the aid of a small force pump. *v* is a forked rod attached to the steering wheel *x*, and descending into holes in the arms of the fore wheels, and having liberty to move up and down, according with the inequalities of the road; the vertical standard, upon which the upper steering wheel *x* is fixed, also forms the centre of motion to the arms of the fore wheels, and is thereby made to direct them in their course.

The advantages contemplated by Dr. Harland in these arrangements, will, we fear, not be realised. In the construction of the boiler, there is nothing upon which we can congratulate him. The attempt to condense the steam has been long since abandoned by those who have had the most experience on the subject; it is evidently impracticable to carry sufficient water to effect even a tolerable condensation; the conducting power of the air is much too slow for the abstraction of the heat, and it should be considered that the air which is liberated from the boiling water, would require a pump to draw it off, which would add complexity to the machinery. With regard to the mode of fixing the cylinder, it differs but little from that adopted by Mr. Gurney. The mode of communicating the power to the wheels is extremely defective, for it will be observed that the *driving* toothed-wheels *m* are (in effect) mounted upon the springs of the carriage, above the *driven* toothed-wheels *n*, by which means they will be continually liable to be thrown out of gear by the motion of the carriage, and the teeth will be liable to break from the same cause.

Patent Method of Propelling Carriages, by Mr. J. Holland. London, 1828.

This invention consists in the application of an arrangement of levers, similar to that commonly known by the name *lazy-tongs*, for the purpose of propelling carriages.

The objects appear to be, to derive, from the reciprocating motion of a short lever, a considerable degree of speed, and to obtain an abutment, against which the propellers should act horizontally in the direction of the motion of the carriage, instead of obliquely to that motion, as is the case when carriages are impelled by levers striking the earth. The drawings attached to the specification seem designed rather to explain the principle, than to represent what the patentee would deem an eligible form of its application.

a is one of the main wheels of the carriage; attached to the axle is a long guide-rod *b b*, extending before and behind, and passing through holes in the blocks *c c*, placed over the beds of the propelling wheels *d d*; *e e* are double palls, acting against two sets of ratchet wheels on the boxes of *d d*; *f f* standards attached to the beds or axles of *d d*, and serving to place them in any required position, by means of the wheels at the top of them; *g g* a series of expanding levers, the central pair playing upon the main axle; *h h* a pair of longer bars, connected with the two bars *g g* at their lower ends, and with each other at their upper ends by a bar, shown by dots, between two uprights; the fulcrum *l*, a lever connected by a rope *m*, with *n*, a counterweight, supported by two short bars *o o*, suspended from the lower ends of two of the bars *g g*. *p*, a fly-wheel, connected with the upper extremities of the bars *h h*, which rise and fall in grooves, in the upright post *q*, the fly serving to equalise the motion. *r* the platform or carriage.

The action is as follows:—Suppose the apparatus in the position shown in the engraving; allow the weight *n* to descend, and the levers *g g* will collapse; but as the wheels *d d* can only revolve in the direction of the arrow, on account of the palls *e e*, the wheel *d* 1 will remain stationary, and the wheel *d*, and the main wheel *a*, will be *drawn* towards *d* 1. On raising the weight, the levers *g g* will be extended, and *g* 2 now becoming stationary, the centre wheel *a* and *d* 1, will be *pushed* forward from *d* 2.

Several of the before-mentioned undertakings to construct locomotive carriages for the common road have either ceased or been suspended, owing to a deficiency of funds to continue their experiments; other undertakings have, however, been commenced, and there are indications of many more candidates for the high honour of accomplishing this greatest of all mechanical works. Among those which have been suspended, that which Sir James Anderson and Mr. W. H. James were concerned in, we have had repeated opportunities of observing most of the difficulties successively surmounted, and such a system of machinery introduced, as bids fair to realise success.

It was in March, 1824, that Mr. W. H. James, of the above firm, took out patents for a steam carriage, the principal arrangements of which are already described at page 529; but it was not until three or four years afterwards that he was enabled to reduce his theories to practice, by the construction of a complete machine, the interim being chiefly employed in the construction of boilers and engines suited to locomotion on the *common road*,—a task found, by experience, to present many unforeseen difficulties.

Having at length obtained the command of a great power, in a very small space, embracing *perfect safety* from explosion, Sir James C. Anderson, Bart. of Buttevant Castle, Ireland, connected himself with Mr. James in the building of carriages. Those who have not had the opportunity (like us) of watching the progress of an undertaking of this kind, cannot well conceive the numerous delays that take place, from various causes, unnecessary to explain. For, however well digested the leading arrangements may appear, improvements are continually suggesting themselves, so as to make it an almost constant doing and undoing, for a considerable period of time. In a machine necessarily consisting of numerous parts, many combinations are required to produce certain effects, which have never been tried, and which cannot be tried, until the whole apparatus be put together. Let the reader now reflect what is the nature of that trial, and how very

different it is from that of a carriage moving upon the hard and almost perfect plane of an iron railway, which allows the wheels to roll with undeviating regularity, and with only a very slight resistance. On the common paved and gravelled road, the varieties of the surface cause a constant succession of violent concussions and vibrations of the machinery, rendering those parts that are connected liable to be strained or broken, and those that work near together, to strike or rub against each other. In every experiment some defect is discovered; then the alteration of one part generally entails the alteration of another, and each successive alteration is scarcely made, than the active mind of the inventor discovers something better, and another arrangement of parts is the result. Thus, while improvement succeeds improvement, *time* proceeds, which induces those persons, who know nothing whatever of the subject, but who wish to appear sagacious, to assert success to be *impossible*, and to ridicule every attempt to attain it. It happens, too, sometimes, that deterioration, instead of improvement, takes place by the successive alterations, and thus the original strongly-framed machine gets cut to pieces, and requires numerous patchings and bracings, that do not confer an adequate strength to compensate for the increased weight.

A four-wheel locomotive carriage, possessing all these disadvantages, and weighing nearly three tons, was started on the 5th March, 1829, on Epping Forest. This ponderous mass of iron and wood was provided with two working cylinders of only 3½ inches in diameter, the power of which was applied to the hind-wheels. The steam was supplied by two tubular boilers, each forming (by the arrangement before described) a hollow cylinder, four feet six inches long, with an internal diameter of one foot nine inches, where the fire was made. With this apparatus the carriage, loaded with fifteen passengers, was propelled several miles on a rough gravelled road, across Epping Forest, with a speed varying from twelve to fifteen miles the hour. It should here be observed that the tubes of which the boilers were composed, were the

common *gas tubes*, in which the seams are formed by bringing the edges together, where they are welded. This process of welding is effected by machinery with great rapidity, and although it answers very well for cold gas at the ordinary pressures, is not adapted for sustaining the pressure of very high steam, together with the effects of the fire, and was only employed in the present instance as a temporary experiment, which also proved its inadequacy, by the seams of one of the tubes opening, and letting the water out of one of the boilers, extinguishing its fire and reducing the intensity of the other, there being a communication between them. Thus circumstanced, with only one boiler in operation, the carriage returned home, at the rate of about seven miles an hour, carrying more than twenty passengers,—at one period, it is said, a much greater number; shewing that sufficient steam can be generated in such a boiler, to be equal to the propulsion of between five and six tons weight.

In consequence of this flattering demonstration that the most brilliant success was attainable, the proprietors dismantled the carriage, and commenced the construction of superior tubular boilers, in which the tubes were of the same internal diameter (one inch), but of greater strength, being three-sixteenths of an inch thick, and the seams welded with a good overlap. Here, however, a new source of vexation took place, from the proprietors not being practically experienced in the quality of iron proper for such purposes, which should be either the very best charcoal iron, or a quality similar to that manufactured by Messrs. Adams, of "Wednesbury Forge," and distinguished by the term *best box-plates*, being used for making the wrought iron boxes to coach wheels. Iron of this kind is so exceedingly tough and malleable, as to "work like lead" (assmiths significantly describe it), under the hammer. The "best London scrap," the "B B," and many other sorts, that are recommended by dealers as of "superior" quality, are decidedly unfit for making tubular high-pressure boilers, wherein the tubes are much bent. Every boiler manufactured by Messrs. Anderson and James, of other kinds

of iron than those above recommended by us, failed; that is to say, fissures were either opened in the bending of the tubes to the required form, or were subsequently opened in the working of the boilers, so as to render them unfit for the object designed. From these causes, great delays and expenses were incurred, and it was not until the month of November 1829, that a small carriage was brought out, represented by the sketch on the preceding page.

The figure exhibits a side elevation, and from its diminutive size, (as shown by the scale) was not intended to carry any inside passengers, but to be employed to drag another carriage behind it. The boilers, four in number, were wholly of wrought-iron tubes, three-fourths of an inch in diameter; and although on the same principle as Mr. James's boiler, previously described, the form of each (instead of circular,) was that of an oblong ellipse, in an upright position, for the purpose of getting as large a surface of metal as possible exposed to the heat of the furnace; as by this arrangement, nearly two hundred tubes, measuring upwards of four hundred feet, were inclosed in a space four feet wide, three feet long, and two feet deep, including the furnaces, (which were inside the boilers), besides the flues and ash-holes. The steam from each of the boilers was conducted into one very strong tube above, of an inch and a half diameter, to supply the engines; each of the pipes of communication to it being provided with stop cocks, to cut off the communication of any boiler that might become unserviceable by leakage, without affecting the pressure on the other boilers. The power was applied through the medium of four working cylinders, which might be considered as separate engines, being fitted so as to work independently of each other, although they might more properly be considered as pairs, each pair acting upon a distinct crank, (the throws of which were at right angles to each other,) that gave motion to its respective hind wheel, on the principle described at page 531. These cylinders were only a foot long, three inches and a half outside, and two inches and a quarter inside, diameter; the pistons were metallic,

making a nine-inch stroke. The cylinders were posited vertically, and vibrated upon trunnions, through which were made the induction and eduction passages, covered by conical valves, forming an external shell to the trunnions, close to their bearings in the plummer boxes.

These engines were arranged at *a*, in a row across the carriage. The steam, after working the engines, passed through two copper tanks, which heated the water therein to such a temperature above boiling, as to melt the soft solder externally upon the vessels, and rendered it necessary to substitute hard solder; the steam was carried thence to the chimney-funnel to escape. At *c* is a door, which space across the carriage, and also that at *d*, were for the use of the man who attended to the furnaces and boilers, besides being used as a receptacle for fuel; at the sides, roof and bottom of this room were plate-iron shutters, to afford constant draughts of air, as the heat would otherwise become insupportable. The engineer sat on the hind seat *p*; and at *e*, over the engines, was a sheet-iron flap, like the lid of a box, and at *f* sliding doors, enabling the engineer to keep his eye upon the working parts, and by his spanners and other tools to rectify, if required, any slight defect that might take place; his situation likewise permitting him to give directions to the furnace-man, and to hold communication with the guide, who sits on the box *q*. At *h* is the steering apparatus, consisting of an external case, containing a vertical shaft, at whose upper end is fixed a bevelled pinion, which is acted upon by a small bevelled wheel fixed into the axis of the double-handled winch *i i*. By turning these handles, therefore, the shaft is caused to revolve, and to give motion to gear at the lower extremity, which acts upon a toothed sector *l*, attached to the fore axletree, and thereby turns the fore wheels into the required positions. The lower gear, which is contained in a box *k*, is adapted to increase the force with a reduced motion, so that the guide, who is able to turn the handles *i i* quickly, operates with great energy upon the toothed sector, and to overcome with facility the most prominent of ordinary

obstacles in the road. This guiding action being administered with a multiplying power, through the complex medium of toothed-wheels, was found to be far more effectual and convenient, than when a long lever of a more simple form was used; besides that the latter was somewhat dangerous to the guide, who was rendered liable to receive severe blows by the motion of the long handle, when the wheels happened to be turned aside by the opposition of stones lying in the road. At *m* is a lamp, not only useful for lighting the road before the carriage, but serving also (as the prow of a vessel to a mariner,) to steer by. The chimney-funnel was made double, the space between the external case *n*, and the internal smoke flue *o*, being for a current of air to prevent the otherwise unpleasant radiation of heat laterally. The fuel preferred was a mixture of coke and wood charcoal, which produced a good heat, and gave off but little black smoke. The motion was communicated to the separate axles of the hind wheels by spur-gear of two velocities, changeable at pleasure, as the state of the road or other circumstances might require: this gear was enclosed in boxes, as shewn at *h*, and the whole machine was placed upon springs, except the guiding apparatus, which was purposely arranged otherwise, as exhibited in the engraving.

The body of the carriage was placed no higher than necessary to obtain security from overturning, and the most perfect safety from personal danger by the sudden extrication of steam, should it happen that a tube were to burst, which was barely possible.

In the numerous experiments made with this carriage, in which the writer had an opportunity of riding, the greatest speed obtained upon a level, on a very indifferent road, was three miles in twelve minutes, (which is at the rate of fifteen miles the hour,) and that was the greatest distance ever ran by it, without some accident occurring to the machinery. The vibration of the parts, either injured or broke something; but what was almost uniformly the case, some of the joints or connexions of the

main steam pipe gave way, which prevented the steam from being conveyed to the working cylinders, either partially or wholly, causing a regular decreasing velocity, until the waste of power, through the increasing size of the fissure, produced an entire stop. The greatest difficulty appeared to be to make steam-joints that would sustain the high temperature, and the shocks and vibrations to which the machinery was subjected by the jolting of the carriage over a stony road. The proprietors of this carriage were, however, unfortunate in never getting any work properly executed; and a capital error was, in our opinion, committed in crowding the machinery into too small a space, which, while it rendered accurate fitting and repairs difficult, occasioned distinct parts to be brought into injurious collision by the motion of the vehicle.

We observed another defect in Messrs. Anderson and James's carriage, (of which the proprietors were fully sensible,) that the periphery or tire of the running wheels was much too narrow, being only an inch and a half. In consequence of which, they sank at least twice the depth into the ground they would have done, had their tires been double the width; an acclivity was thus constantly being formed before the wheels, which they had to ascend, or to continue the crushing operation. Much ground, it should be observed, that will resist compression entirely from a broad wheel, and allow the carriage to roll over with but comparatively trifling resistance, will give way under a narrow wheel loaded with a similar weight. The chief disadvantages of broad-tired wheels, consists in their augmented weight, and their greater liability to encounter loose stones lying on the road. The narrower a wheel is, the better, provided it does not leave an impression in the road; but as wheels should be made to suit all the various conditions of the road on which a carriage has to travel, we are disposed to think a width of three inches, to a pair of wheels bearing thirty hundred weight, to be a good proportion.

In every experiment made with this carriage, the

failure of effecting all that was expected, could uniformly be traced to some evident cause; and we believe it will generally be found, that those individuals who have had the most experience in undertakings of this kind, see nothing of an insuperable nature in the obstacles that have hitherto presented themselves.

At the present time, (September 1830,) there are five or six different steam coaches, for the common road, in the course of building and experimenting; amongst which, one belonging to Mr. Hancock, of Stratford, Essex, and another to Messrs. Ogle and Summers, have made very frequent and favourable indications of ultimate success. It formed a part of our plan to include a description of the last-mentioned locomotives in this place; existing circumstances, however, preclude that being now done, but should an opportunity be soon afforded to us of inspecting the carriages, a description of them will be given at the close of this work, which the reader can ascertain by consulting the index.

The steam engine is, however, not the only locomotive power either proposed or used for the common road. Mr. Samuel Brown has actually applied his gas-vacuum engine (described at page 257) to the propelling of a carriage, but the great bulk and weight of his apparatus, in order to produce the required power, seem to render his project almost hopeless.

The elasticity of our atmosphere has been proposed to be applied to locomotion in a variety of ways. One of these was by employing heat to expand the air in a close cylinder, to operate upon a piston, and by the subsequent action of a cold medium to condense it.

Another mode, which has been proposed by several individuals, is that of employing atmospheric air in a highly compressed state. No less than four individuals *occur* to us, who have recently taken out patents for the same invention (and we think there are others besides), which circumstance exhibits in a strong light the ignorance (to use the mildest term) of the patent agents concerned. The patentees' names alluded to are Medhurst, Wright,

Bombas, and Mann. The last-mentioned individual (Mr. William Mann, of Effra Road, Brixton, Surrey,) has recently published a lithographic print of his carriage, of which the reader will find a drawing, in the fifth volume, new series, of the Register of Arts. Mr. Mann has, however, omitted to supply those details, by which alone we could decide upon its feasibility.

Mr. Mann proposes, like his predecessors, to employ a series of strong metallic recipients, similar to the cylindrical vessels used for portable gas, into which thirty or more atmosphères are to be condensed by the power of a steam engine, water mill, or other adequate prime mover. A sufficient number of these vessels are stowed in a case adapted for the purpose, which is to be fixed underneath the carriage; a tube communicating with all the recipients, is to convey the compressed air to two working cylinders, having the apparatus common to high-pressure steam engines, the piston rods of which will give motion to a crank on the axis of the hind running wheels. It is proposed to work expansively, and to vary the cutting off the stroke, according to the degree of elasticity of the air.

The velocity Mr. Mann proposed to travel was fourteen miles in the hour, which he calculates will require two thousand cubic feet, of the natural density, to propel a carriage weighing, with its load, two tons. When the roads are in a bad state, it is intended to charge the vessels with a greater number of atmospheres, to overcome the increased resistance.

The patentee states, that the carriage is *constructed* (?) to carry seventy-five cubic feet of compressed air, which, at a density of thirty-two atmospheres, is sufficient to propel it fourteen miles; and if the air were compressed to be equal to forty-eight atmospheres, that quantity would propel the carriage twenty-three miles; and if to sixty-four atmospheres, thirty-four miles. The average cost of the power is calculated at one penny per mile; that is, if a steam engine be employed to effect the compression of the air into the recipients, the cost in coals of such

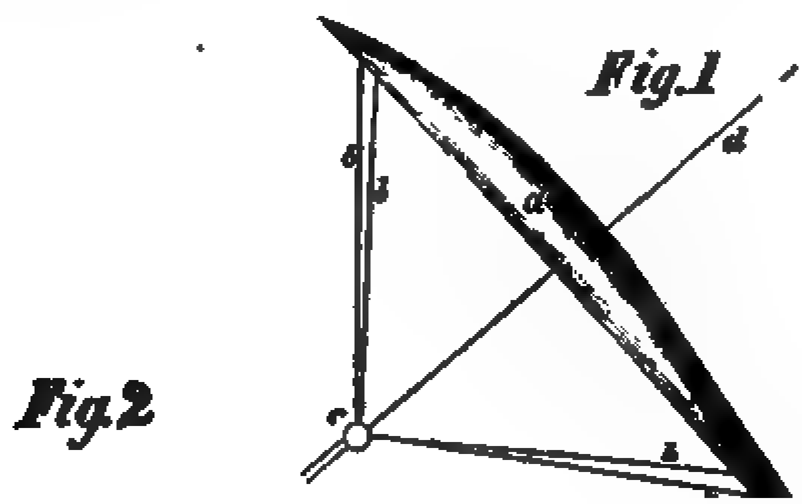
steam power, to condense a volume of air sufficient, by its subsequent expansion, to propel a carriage one mile, is one penny. Mr. Mann, however, must know that this would only form one item in the expense of working a carriage. The proposition of propelling by a process of this kind, is certainly specious, but those who have given the subject their best attention, consider that no practical means have yet been devised to compensate for the constantly decreasing expansive force of the air in the recipients.

Various modes of employing the atmosphere as a locomotive power have been put in practice many years ago. In Holland, four-wheeled carriages were propelled by the wind, more than a hundred years since, by the application of suitable sails and rigging to the carriage, but the variableness in the force as well as direction of the power, render such a mode of transport ineligible, except under peculiar circumstances and localities. In those countries where the wind blows constantly in one direction, during a great period of the year, it requires no gift of prophecy to foretel that the inhabitants will, ere long, become possessed of sufficient mechanical knowledge, to take advantage of that circumstance, and make it subservient to their wants or pleasures. It is evidently of little consequence "which way the wind blows," provided it is nearly in one line, (whether east to west, or west to east) as the motion may be reversed without any material loss of power, by means of a pulley-wheel; the sails of those carriages having the wind in their favour, being spread, and drawing other carriages in the opposite direction, with their sails furled. Of course, railways (and especially Mr. Palmer's elevated single rail)* would render such a mode of communication across a country of the utmost efficiency and importance.

The celebrated Dr. Franklin shewed many curious and somewhat useful applications of the wind, through the

* See a plan for this purpose, suggested by the writer, at page 114, vol. 1, of first series of Register of Arts.

medium of kites; but by the patented invention of Colonel Viney, and Mr. George Pocock, methods have been introduced of regulating the force derived from the wind, and of varying its direction so as to apply it successfully to the propulsion of a carriage. This was proved by a journey made in 1826, by the before-mentioned gentlemen, from Bristol to London, in a carriage which they denominated a Charvolant.



The Patent Charvolant, by Messrs. Viney & Pocock. 1826.

The patentees attach to the car, or *vessel*, the cords of one or more kites, according to the force of the wind and the resistance to be overcome. The kite *a*, fig. 1, is jointed in the middle, so that it may be folded up, and carried or stowed away with greater facility, and that it may be

adjusted so as to present to the wind a surface of any required dimensions; this is effected by the four cords, *b b b b*, which are brought together by passing through the dead eye *c*, whence they proceed to the car, and are arranged to the required lengths by the persons therein. The cords are also used for regulating the direction of the power; by shortening those on the right hand, when the car is required to be turned to the right, and those on the left hand, when it is required to be turned to the left. But the charvolant represented in the preceding fig. 2, is principally guided by the T handle, and stem *e f*, which operates on the axis of the fore wheels, by means of an endless band or cord passing about the pulley *f*, fixed on the lower end of the stem *e f*, and the pulley *g*, fixed on the bed of the axle-tree of the fore wheels. The machine is stopped, or its motion retarded, by the drag *k*, which is attached to the perch by a spring, to keep it off the ground, till the motion is required to be retarded or the car stopped, when its fluke-end is pressed into the earth by the lever *h*, acting on the connecting piece *i*.

When great power is required, two or more kites are placed in succession, one behind the other, and so attached by cords, that whatever motion or direction is given to one, will be communicated to the others.

The patentees purposed to attach occasionally to their car a platform on small wheels, with the view of carrying a pony, to be employed in dragging the machine (which is exceedingly light) in cases where the kites cannot be applied.

Although the arrangements introduced or suggested may contain many imperfections, in common with schemes which have not been corrected by experience, Messrs. Viney and Pocock have the merit of making an important step towards rendering this powerful agent of Nature serviceable to man.

The reader will observe that we have hitherto treated only of locomotion as applied to our common earth or paved roads, an art which may be regarded as still in its

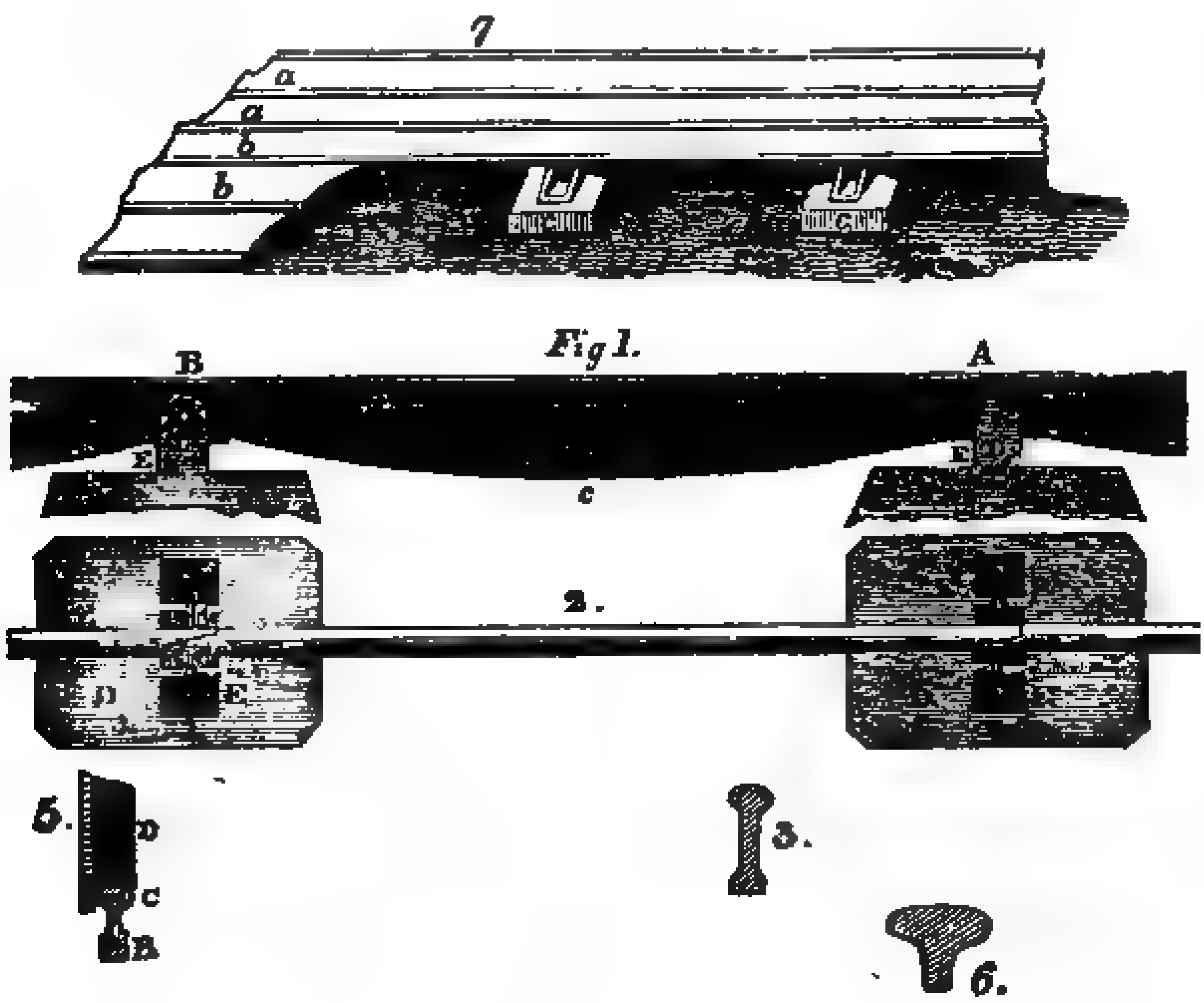
infancy. This is not the case, however, with locomotion on rail-ways, which appears to have nearly attained maturity, and to be rapidly advancing towards perfection. The latter, however, never presented a tenth part of the difficulties of the former, owing to the rail-road and the carriage being purposely adapted to each other. Those rail-road engines, of which the public have had such remarkable accounts of their performances, do not possess a power adequate to propel them a mile in an hour on the common road; probably, not sufficient to move them at all.

Previously to our giving an account of the rail-way locomotive engines lately introduced, it is necessary that the reader should be informed of the nature of the surfaces on which they are made to operate, as therein consists one of the principal causes of the effects produced. The rail and the carriage may, in fact, be considered as two parts of the same machine, as the one is inoperative without the other. Under this view of the matter, we annex a brief historical and mechanical description of the various kinds of rail-ways introduced, as strictly belonging to this section of the Appendix.

There are three distinct kinds of rail-ways, namely, *edge*, *tram*, and *suspension*. The oldest and most extensively adopted plan, consists in laying rails of wood or iron for the use of carriages, with guiding flanges on the wheels; these are now termed edge rail-roads, in consequence of the iron rails being narrow and deep.

Edge rail-ways were first constructed of wood in the neighbourhood of Newcastle, for the purpose of conveying coals to the side of the river Tyne; and, occasionally, these wooden rails were covered with plates of wrought-iron, in the parts liable to much wear. In adopting cast-iron for rails in the same neighbourhood, the same kind of wheels and the essential structure of the rails were preserved, the sole difference being in the circumstances which the use of a new material rendered necessary. Figs. 1, 2, and 3, annexed, show the side-view, the plan, and the cross section of a cast-iron edge-rail, of the form which 's adopted in the best rail-ways on the banks of the

Tyne and Wear. The waggons run upon the rounded edge of the rail, which is smooth, and laid as evenly and regularly as possible. The length of these rails is usually three feet, with a depth of about four inches and a half in the middle, and breadth of the top two inches; but in some rail-ways the rails are four feet long. The ends of the rails meet in a piece of cast-iron, called a *chair* (see fig. 4), and the chairs are fixed to blocks of stone called sleepers, with a broad base, and weighing from one and a half to two hundred weight. These are firmly bedded in the ground, and adjusted to a proper plane for the road before the chairs are connected to them. The goodness of the road depends much on fixing the sleepers in a sound, firm manner.



In fig. 1, the side-view of the rail, C, is shown, supported at the extremities A B, by cast-iron chairs E E, which rest on blocks of stone D D, called sleepers.

Fig. 2, the plan, shows the scarf joints, where the ends of the rails meet in the iron chairs E E. Fig. 3, the cross section of the rail, taken at C in fig. 1, which is the middle of its length. Fig. 4, is a cross section at B, through the joint-chair and supporting block.

It has already been noticed, that malleable iron was occasionally used for protecting wooden rails, but it appears to have been first employed for the rails themselves by Mr. George Grieves, at Sir John Hope's collieries near Edinburgh; these were made of inch and quarter bars, and used for very light work only. Malleable iron rails of a stronger kind were used by Mr. Neilson of Glasgow, for a rail-way on the property of the Earl of Glasgow, commencing at the Hurlet coal and lime works, and extending to the Paisley canal, a distance of two miles and a half. The length of each rail being nine feet, it is supported at every three feet, and is two inches and a quarter deep, and three quarters of an inch thick; the waggons carry about thirty-five hundred weight each.

Malleable iron rails, formed of rectangular bars, must obviously present too small a surface for the wheels to run upon, or otherwise require more materials than it would be consistent with economy to employ; and to obviate this difficulty, a patent was obtained by Mr. John Birkinshaw, of Bedlington Iron Works, Durham, for an improved form for the bars to be used as rails. It consists in giving the bar the form of a triangular prism, or such variation of that form as is best adapted for that purpose. Fig. 5, C B, (in the preceding engraving) represents the section recommended by Mr. Birkinshaw, and he proposes that the rails should be eighteen feet in length. Fig. 6, represents another form, which is evidently better. His suggestion, respecting welding the joinings, would rather be injurious than useful, owing to the expansion in length by increase of temperature.

The chief advantage of wrought-iron rails is that of reducing the number of joints; and the difficulty of making the rails perfectly even at the joints has contributed much towards their introduction.

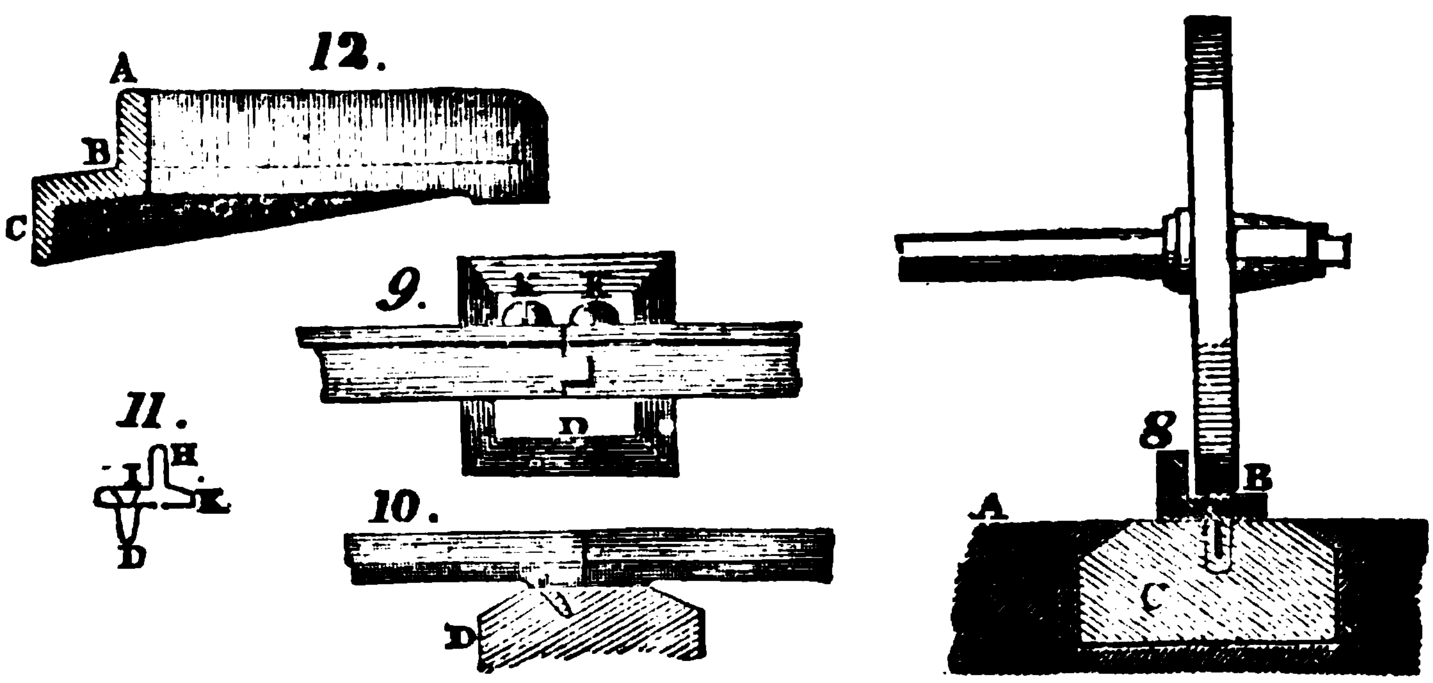
Edge-rails are most adapted for permanent works. They are of such a nature, that ordinary carriages cannot be employed upon them; but on any rail-way where such carriages can be used, they must do more injury to the surfaces of the rails, than will be equivalent to the advantage of suffering them to go there. Consequently, a rail-way with edge-rails, is much more likely to be kept in good order than any other. It is of the utmost importance in a rail-way, that the upper surface of the rails should be perfectly even and smooth; the very object of putting down rails was to obtain such surfaces; but they would be kept in order only a very short time, if carts or waggons from a common road were allowed to turn on to them with wheels covered with gritty mud, while the temptation to use a rail-way in this manner is great; for the load which required a horse on the common road, might be drawn by a man on the rail-way; thus enabling them to go at a greater speed, and yet with less injury to the horses.*

Tram-ways, or *tram-roads*, differ from the preceding kind, in having the guiding flanges upon the rails, instead of upon the wheels of the carriages; it gives the advantage of employing carriages that can be used where there are not rails laid down. They are called *tram*-roads, from their being first used for drawing trams upon. The tram-rail is exceedingly convenient for temporary uses, and in its ordinary form (as represented at fig. 8, in the subjoined engraving,) it is much used in quarries, in mines, in forming new roads, in digging canals, in conveying large stones for buildings, and other purposes. Tram-rails are of a very weak form, considering the quantity of iron in them, and in some works it has been found necessary to strengthen them, by adding a rib on the under side. Fig. 12, shows half a tram-rail of this kind in perspective, A being the guide; B the bed of the rail, in which the wheels run; C the rib on the underside to strengthen it. The rails used for repairing the Surrey tram-roads were of this form, and it certainly renders them very strong.

* Tredgold on Rail-ways, page 32.

As tram-rails are applied with so much benefit in forming temporary ways, the most convenient and ready mode of putting them down is an object of some importance. The common method is to fix them with large nails or spikes upon cross sleepers of wood. The chief inconvenience of this plan is the difficulty of driving and drawing the nails, when they have to be changed.

For permanent roads, the rails are usually fixed by spikes driven into wooden plugs, previously inserted in the blocks of stone for supporting the rails, as shown in fig. 8; where B shows the tram-plate (in section), with one of the running wheels of the carriage thereon; C the stone sleeper, in which is inserted the wooden plug to receive the nail; A is part of the gravelled horse-path or road.



An attempt to improve the method of putting down tram-plates, by Mr. Le Caan, affords great facility in taking up or putting down the rails; they are contrived so as to fix one another, without the aid of nailing. Fig. 10, represents a longitudinal section of two of these plates, placed on a stone sleeper *d*, and fig. 9 is a plan of the two plates. The plates are joined by a dove-tailed notch and tenon, and an oblique plug is cast on each plate, which is let into the stone sleeper. But, for the advantage of taking up the plates, to repair any defect, there are plates at every thirty yards, with perpendicular plugs; such plates are called stop plates. The diameter of the plug

near the shoulder is one inch and three quarters, at the point one inch, its length is two inches and a half, and its obliquity, shewn in figure 10, about eight degrees. A small groove in the whole length of the exterior of such plug, is made to allow the water in the hole to expand in freezing, and it also serves to admit a wire to draw a broken plug out by. The holes for the plugs should be cut to the depth of three inches, by a standard guage of cast-iron, and counter-sunk, so as to allow the end of the plate to bed firmly on the block which supports it.

Fig 11, is one of the ends of a tram plate, in which H shews the flange or upright edge; *i* the flat part or sole, in which the wheels of the waggon run; D one of the plugs, and K a projection behind, to render the plates firmer upon the blocks. The usual length of one plate is three feet; the flanch H, is one and a half inch high; the sole, or bed, three and a half or four inches broad, and three-fourths of an inch thick, but these dimensions are varied according to circumstances; the most approved weight has been forty-two pounds for each plate. The ends from which the plugs project, under which the tenons and notches are made, should be a quarter of an inch thicker than the other parts of the plate.

The weight of the blocks or sleepers should not be less than about one hundred and twenty pounds each; and some kinds of ground will require heavier.

In this method the wheels of the waggons cannot be obstructed by the heads of the nails rising above the surface, and the blocks are not disturbed by fixing the plates; and when repairs are necessary, the plates must be formed for the purpose.*

When tram-plates are fixed by spikes to stone sleepers, there is some difficulty in keeping the joint even and in its place, but it seems to be successfully obviated by using a saddle piece to receive the ends of the nails at the joints, an improvement which was introduced by Mr. Wilson on the Troon tram-road.

* Transactions of the Society of Arts, &c. vol. 25, p. 87, 1807.

Tram-roads are much esteemed in Wales; and, in consequence of using them, it is found desirable to divide the pressure upon the rails as much as possible; hence, small carriages are used, and these lead to small wheels, so that the effect of a given power is not above half what it ought to be; and yet the enormous increase of rail-roads in Wales renders it evident that some benefit is received from adopting this system of conveyance. In 1791, there was scarcely a single rail-way in South Wales; and in 1811, the complete rail-roads, connected with canals, collieries, &c. in Monmouthshire, Glamorganshire, and Caermarthenshire, amounted to nearly 150 miles in length, exclusive of underground ones, of which one company in Merthyr Tydvil possessed about thirty miles. During the last nineteen years there has been a considerable augmentation of rails in almost every district, and it is probable the total length does not now fall short of two hundred and fifty miles!

The third kind of rail-ways mentioned, are those on the principle of suspension, of which that invented by Mr. H. R. Palmer is, we believe, the earliest and the best.

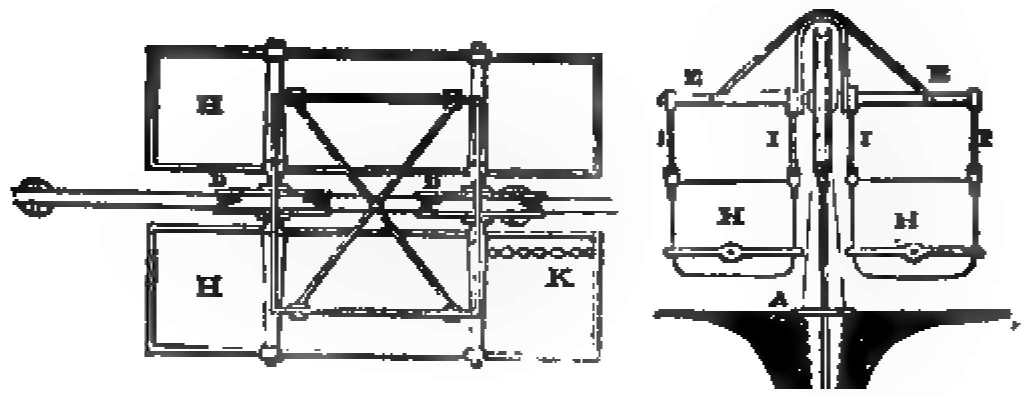
Instead of *two lines* of rail laid upon the *ground*, Mr. Palmer's railway consists of only *one line*, which is elevated upon pillars, about nine feet apart, and carried in a straight line across the country, however undulating or rugged, over hills, valleys, brooks, and rivers; the pillars being longer or shorter, to suit the height of the rail above the surface of the ground, so as to preserve the line of the rail, which is always straight, whether the plane be horizontal or inclined. The carriage has only two wheels, placed one before the other, (to travel in the single rail), connected by a suitable frame-work; the axles of the wheels are lengthened, so as to form extending arms of support, to which are suspended the receptacles for the goods or passengers, one on each side of the rail, with their centre of gravity below the surface of the rail. The rods by which the receptacles or waggons are suspended are inflexible; hence, although the weights on each side be not equal, they will nevertheless be in equilibrio, as

may be observed in a ship, which, when unequally loaded, assumes such an angle with the surface of the water as preserves the equilibrium. We have observed that this arrangement will admit of a considerable inequality of the loads in the opposite vehicles, without producing any inconvenience, which is partly owing to the change of fulcrum, or bearing upon the rail. The breadth of the rail is about four inches, and slightly convexed, so that an additional weight put into one of the receptacles, causes the wheels to incline a little to that side, and to bring the fulcrum nearer to the augmented weight, reducing the leverage on that side, and in the same proportion increasing it on the other; so that an equal distribution of the load is not necessary, although it is preferable, and can in most cases be easily effected. The rail is made capable of adjustment, so that it may be kept straight and even.

A number of carriages are linked together; and either drawn by a locomotive machine upon the rail, or towed along by a horse, as barges in a canal. By the latter mode, the horse, owing to the undulations of the surface in which he travels, will sometimes be much below the rail; to preserve, therefore, a proper angle of draught, a sufficient length of rope is provided.

Fig. 1, is an end-view of the carriage, with a cross section of the rail, and a pillar shewing its form and manner of fixing. Fig 2, is a side-view of the rail-way, passing over an uneven surface, with three of the supporting pillars of unequal length. Upon the upper surface of the rail, are seen the two carriage wheels, and the manner of suspending the waggons or receptacles from the axletrees, which is however better shewn by the rods IIII, in fig. 1. Fig. 3 is a plan exhibiting the manner the receptacles are braced together. In the several figures, similar letters indicate corresponding parts.

A, fig. 1, is an upright pillar of cast-iron, having at the shoulder a flange, which rests upon the surface of the ground. The pillar is formed with ribs at right angles, which converge towards the lower extremity, and are

2  1

Palmer's Patent Suspension Rail-way, and Carriages. 1822.

notched in the edges for the better securing it firmly in the ground. The hole in which it is inserted is to be previously well rammed, by a kind of pile-driving engine, and the foot of the pillar surrounded with hard materials, which are also to be rendered as compact as possible. Three of these pillars are shewn fixed in fig. 2, placed about nine feet apart. At the upper extremities of the pillars are long clefts, or openings, to receive the rail B;

which is composed of deal planks, set on their edges, with their upper surface C, defended by cast or wrought-iron plates, a little convex on the upper side.

When the rail has been some time in use, and all has taken a bearing, a little adjustment of the line may be requisite, before the rail is bolted to the pillars; to effect which, a very simple and easy method is provided. In the cleft of the pillars, and under the rail, two wedges *a a*, are introduced, in opposite directions, whereby its level may be adjusted with the nicest accuracy.

The wheels D D, are provided with flanges, to keep them on the rail, and their peripheries are slightly concave, to adapt their surfaces to that of the rails. E E, are the arms or axles; H H, are the receptacles for the goods, which are made of plate iron, and are suspended to the arms, (as before mentioned) by the inflexible rods, IIII. To one of the arms a chain, K, is hooked, to which a towing rope may be connected. Any number of carriages may then be attached together by chains hooked on to the angles.

Fig. 4. is intended to exhibit a portion of the rail-way in use, and the methods by which several of the obstacles which frequently present themselves are overcome. On the left is seen a jointed rail, or gate, that crosses the road, over which the carriages have just passed, and the gate swung back to leave the road open; the horse and man having just forded, the train of carriages is proceeding in its course, and following another train, part of which is seen on the right, crossing a *rail bridge*, simply constructed for that purpose. Provision is made for trains of carriages that are proceeding in opposite directions, by means of "sidings" or passing-places.

With respect to loading—if both receptacles be not loaded at the same time, that which is loaded first, must be supported until the second is full. Where there is a permanent loading-place, the carriage is brought over a step, or block; but when it is loaded promiscuously, it is provided with a support connected to it, which is turned up when not in use. From the small height of the carriage,

the loading of those articles usually done by hand, becomes less laborious. The unloading may be done in various ways, according to the substance to be discharged, the receptacles being made to open either at the bottom, the ends, or the sides. In some cases it may be desirable to suspend them by their ends, when, turning on their own centres, they are easily discharged sideways.

Among the principal advantages contemplated by the adoption of Palmer's rail-way, may be mentioned that of enabling the engineer, in most cases, to construct a rail-way on that plane which is most effectual, and where the shape of the country would occasion too great an expenditure on former plans; that of being maintained in a perfectly straight line, and in the facility with which it may always be adjusted; in being unencumbered with extraneous substances lying upon it; in receiving no interruption from snow, as the little that may lodge on the rail is cleared off by merely fixing a brush before the first carriage in the train; in the facility with which the loads may be transferred from the rail-way on to the carriages, by merely unhooking the receptacles, without displacing the goods, or from other carriages to the rail-way, by the reverse operation; in the preservation of the articles conveyed from being fractured, owing to the more uniform gliding motion of the carriages; in occupying less land than any other rail-way; in requiring no levelling or road-making; in adapting itself to all situations, as it may be constructed on the side of any public road, on the waste and irregular margins, on the beach or shingles of the sea-shore,—indeed, where no other road can be made; in the original cost being much less, and the impediments and great expense occasioned by repairs in the ordinary mode, being by this method almost avoided.*

As Mr. Tredgold's opinion has justly great weight in subjects of this nature, we annex it, on Mr. Palmer's railway, in this place.

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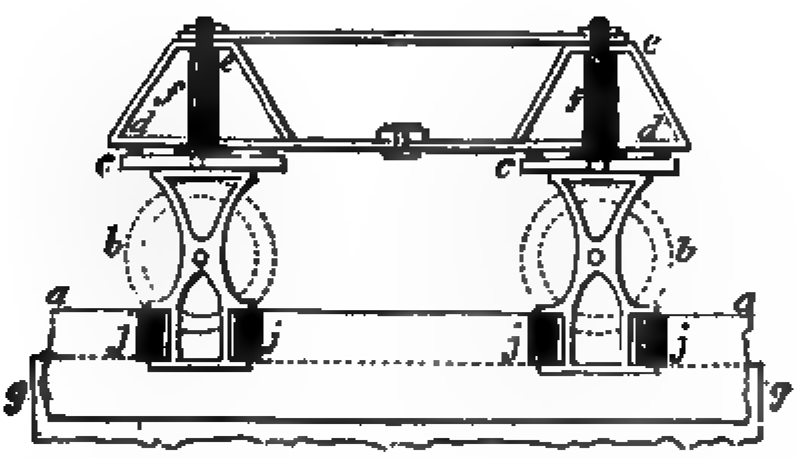
* See Palmer's "Description of a Rail-way on a new Principle." Taylor, London.

"We expect that this single rail-road will be found by far superior to any other for the conveyance of the mails and those light carriages, of which speed is the principal object; because we are satisfied, that a road for such carriages must be raised so as to be free from the interruptions and crossings of an ordinary rail-way. A carriage moving at a greater velocity than six miles per hour, on a rail-way, must be raised so as to remove the possibility of overrunning people, or of dashing against other vehicles. Carriages running smoothly and rapidly, with a small moving power, cannot be suddenly checked; and they admit of no change of direction. But, were a rail-way elevated ten feet above the common roads, these accidents could not take place, except through neglect; the passengers would not be raised to a much greater height than the top of a common coach, and in a suspended carriage which could not possibly overturn."*

In 1828, Mr. T. Chapman, of Royal Row, Lambeth, suggested an improved carriage from Mr. Palmer's railway, for which he received a reward from the Society of Arts. By Mr. Palmer's method of making turns in the road, a portion of the rail is made to turn with the carriage on it, which has certainly some disadvantages; to obviate which, Mr. Chapman has contrived a carriage that will itself turn on a fixed rail, whether curved or straight, or from one angle to another.

Fig. 1, exhibits an end-view of the carriage on a section of the rail, and fig. 2 is a side-view of the same, partly in section. *a a*, is the rail; *b b*, two wheels on the rail; these carry the turning plates *c c*, each having four friction rollers; *e e*, upper plates; *f f*, the vertical axis of the wheel frames, or turn plates, *c c*; they pass through the plates *d*, and *e*, from which the boxes *g g* are suspended, by the lateral arms *h h*, and *i i*. Now, as the wheels and frames *b*, *c*, can turn freely on their axis *f f*, they each require four grinding rollers, *j j j j*, to keep them in a right

* Tredgold's Treatise on Rail-roads and Carriages, (p. 87). Taylor, London

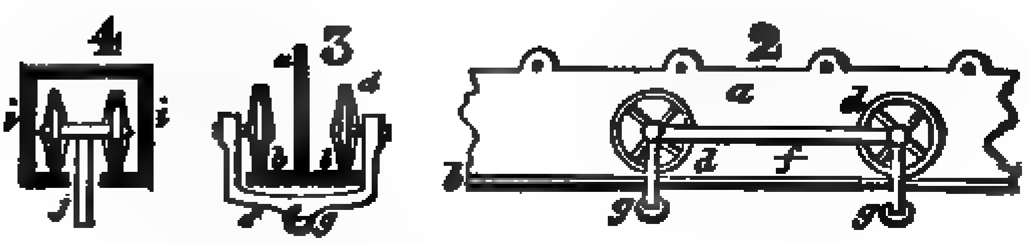


(*Chapman's Modification of Palmer's Rail-way Carriage.* 1828.)

line with the rail, and to cause them to turn as the rail turns. These carriages should not be farther asunder than is absolutely necessary for the required curve of the rail. The bottom of the carriage has a joint at one third of its length, and is held up at this by the hooks *k k;* by removing these, the contents may be let out; the fixed portion of the bottom is made sloping, so that it may be readily emptied.

Two or three years after Mr. Palmer had brought out his plan of rail-way, a suspension rail-way was patented by Mr. J. J. Fisher, for a similar though less perfect arrangement, and, as we should suppose, somewhat trespassing upon Mr. Palmer's patent right. Mr. Fisher, it is true, suspends his carriages to two lines of rail, but he was, in

this respect, anticipated by Mr. Palmer, who says "to elevate two lines of rail for the purpose of supporting a carriage, could not be done at a sufficiently moderate expense; I therefore endeavoured to arrange the form of a carriage in such a manner that it would travel upon a single line of rail, without the possibility of overturning." Mr. Fisher's plan may, however, possess some originality, and, with some modifications, may be rendered useful. The chief object is stated to be the throwing of a rail-road across rivers, swamps, &c.; and the means proposed of effecting it will be readily perceived, upon inspecting the annexed diagrams, and referring to the subjoined explanation of them.



Fisher's Patent Rail-way and Carriages. 1824.

Fig. 1, is a side-view of the proposed rail, attached, by vertical rods, to a chain of bars, which form a catenarian curve; fig. 2, is a similar view, but giving only a portion of fig. 1, on a larger scale; fig. 3, is an end or sectional view of fig. 2; fig. 4, is also a sectional view, but of another form of rail, which we shall describe lastly. The letters of reference denote similar parts in each of the figures.

a is the rail, made of stout cast-iron plates of uniform dimensions, bolted together; having a horizontal projection or plate, *b b*, on each side, for the wheels of the carriages, *d d*, to run upon, (seen best in fig. 3.); *f f* shews the frame of the carriage; the manner of connecting the

wheels on either side of the rail in pairs, is exhibited in fig. 3, and the mode of joining the front with the hind pair of wheels, in fig. 2. Iron rings, *g g*, pass through the centres of the lower parts of the carriage-frame, to which are suspended the boxes or receptacles for holding the goods or passengers, one of which is shewn attached at *h*, fig. 1. The loops or holes in the upper part of the rail *a*, fig. 2, are, of course, for the convenience of bolting it to the suspension bars, as seen connected in fig. 1. Each of the bars is to be provided with a wedge or screw adjustment, so as to regulate the uniformity of the plane, when any part sinks.

To give an idea of the other form of rail, the section fig. 4, is sufficient. Here it will be seen, that the rail, (if we may so term it) is of the form of a square tube or hollow trunk *i i*, with an opening or slit on the lower side for the bar, *j*, (which is fixed to the axletree of the carriage) to pass through, for the purpose of being connected to a box or receptacle underneath. This square cast-iron trunk or rail, is to be suspended, as in the previously described rail, to a chain of iron bars or wires, drawn nearly tight, so as to form a catenarian curve, when stretched over the place to be crossed.

The mode of propelling the carriages is, we believe, not stated in the specification, but we understand it is to be performed, when the rail-way is on a horizontal plane, by elevating that end in which the carriages are placed, and letting them find their way to the other end by their own gravity. By such a proposition, it is evident that the patentee does not intend it for any extensive work, as the means proposed of producing motion, are applicable only to narrow rivers and ravines.

Having now noticed the three principal kinds of railways, it is very important to know the effect produced by a given power applied to each; and this knowledge has, we believe, been very faithfully furnished to the public by Mr. Palmer, who made a series of very careful experiments on several of the principal railways of the kingdom, which he published in his work before alluded to.

The results of these experiments we annex, preceded by some introductory observations of the writer on the subject.

"Perhaps," says Mr. Palmer, "if some accurate means of ascertaining the resistance of roads and railways were, on all occasions, used, their improvement would be much advanced. The real value of either being then unequivocally compared, the amount of defect could no longer be a matter of mere opinion. The proprietors would then know whether an apparent inferiority arose from the difference of horses, or difference of circumstances; and it would be of great advantage to introduce a clause in contracts, which would determine the effect to be produced. The methods by which resistance of roads and rail-ways has been ascertained, have not been sufficiently accurate, or have been too inconvenient for general use. The dynamometers, which denote the resistance by the degree of extension given to springs attached to the carriage, are convenient as portable instruments, but do not denote the measure with the necessary precision. The resistances are not equable from the irregularities of the surface; neither does the force which draws the carriage continue equable. When horses are employed, those instruments are of no service whatever. The effect of the unequal force or resistance occasions a vibratory motion to the indicating point, and we can never have confidence in any result they exhibit. Similar defects are observable in all the instruments I have seen.

"Having had frequent occasion to ascertain these resistances, I constructed an instrument which, by removing the imperfection referred to, has been completely successful. The problem was to make such an instrument as would indicate very small differences, but which would not yield *suddenly* to a change of resistance. I therefore connected to a spring dynamometer, a semicircular close copper vessel containing water; at the centre is a spindle, on which an arm or fan is fixed, and which very nearly corresponds with the inside of the vessel. The springs

are so connected with the spindle, that they cannot be acted upon without the arm or fan turning upon its centre, and passing through water. In order to pass through the water, the latter must escape by its sides; and the space being extremely small, *it cannot pass rapidly, but will yield to the smallest force.*

"By way of exhibiting the difference of resistance upon different rail-ways, I have attached a table containing experiments on several.

"The first column contains the articles conveyed; the second, the resistance in proportion to the weight; the third, the whole effect produced, *i.e.* including the weight of the carriage by one horse, or one hundred and fifty pounds, at two miles and a half per hour; the fourth, the useful effect, or the load conveyed, in pounds; the fifth, the same, in ordinary measures; the sixth, the inclination, expressed by decimal fractions, on which a rail-way, whose resistance is equal to that specified, should be constructed, that the resistance of the loaded carriages downwards, may be equal to that of the empty carriages upwards; the seventh, the effect produced under such circumstances; the eighth, the useful effect under the same, the weight of the carriages being deducted. In each experiment, the power of the horse is assumed at one hundred and fifty pounds, moving at the rate of two miles and a half per hour.*

* In the inclinations, the weight of the horse itself, as part of the effect produced, is not taken into account, that the table may equally serve where mechanical force is applied. Some allowance must therefore be made, where horses are used, but the difference in the inclinations given will be very trifling.

" *TABLE exhibiting the amount of Resistance in a straight line upon several Rail-ways; also shewing the effect which can be produced by a force of* 150 *lbs. at two miles and a half per hour, being that exerted by an average good horse, through an ordinary day's work.*

No. of Exper.	LIST OF RAIL-WAYS.	1 Materials conveyed.	2 Resistance in proportion to the weight.	3 Effect produced on a level by a force of 150 lbs. at 2½ miles per hour.	4 Useful effect or weight in pounds, carriages deducted.	5 Useful effect in tons and parts.	6 Proper inclination for a descending trade.	7 Effect produced on the proper inclination by 150 lbs. carriages included.	8 Useful effect on the inclination.
						Ton. cwt. lbs.			
1	Llanelly Tram Road, S. Wales..	Coals.	$\frac{1}{59}$	8850	4602	2 1 10	,005953	6 1 92	3 3 38
2	Surrey Tram Road.............	Chalk.	$\frac{1}{60}$	9000	6750	3 0 30	,010000	10 0 100	7 10 75
3	Penrhyn Slate Quarries, edge Rail Road, curved surface.........	Slate.	$\frac{1}{87}$	13050	10084	4 10 4	,007237	15 14 68	12 3 12
4	Cheltenham Tram Road........	Coals.	$\frac{1}{90}$	13500	8679	3 17 55	,005263	11 9 4	7 7 27
5	New Branch of ditto, slightly covered with dust..............	Do.	$\frac{1}{122}$	18300	11765	5 5 5	,003883	15 10 53	9 19 67
6	Ditto, swept clean..............	Do.	$\frac{1}{146}$	21900	14079	6 5 79	,003244	19 11 59	11 18 95
7	Edge Rail Roads, near Newcastle upon Tyne..................	Do.	$\frac{1}{170}$	25500	17773	7 18 77	,003146	24 9 59	17 1 21
8	Railway invented by H. R. Palmer	Do.	$\frac{1}{300}$	45000	33750	15 1 38	,002000	50 4 52	37 13 39

"*Note.*—I am indebted to Mr. GRIMSHAW, of Sunderland, for the data of No. 7."

It has, we believe, been a generally received opinion, that carriages on a rail-way cannot be propelled by locomotive power up an inclined plane that rises more than twenty feet in a mile, without the assistance of indented or toothed-rails to increase the resistance, and thus prevent the carriages from slipping back. By Mr. W. H. James's invention, this difficulty is overcome, so that a train of carriages may be made, by a locomotive engine, to ascend and descend inclined planes of any elevation necessary in the construction of rail-roads, and over very smooth and almost polished surfaces. We understand that the most satisfactory proofs have been afforded of the ability to effect this, by repeated trials on a rail-road more than a hundred feet in length, laid down for the purpose of experiment; on which it was found that a train of carriages would (with the patentee's machinery) ascend inclined planes of three inches in the yard, which is equal to four hundred and forty feet in the mile. This important advantage is gained by applying the power to the axletrees of the wheels of the several carriages in the train, by means of the rotation of a long horizontal rod (or series of connected rods) actuated by bevel gear under each carriage.

An ingenious plan has also been proposed by Mr. James for enabling the carriages on a rail-way to pass around turns or curves in the road, without additional friction For this purpose, the horizontal rotatory shafts, which cause each pair of wheels in the train to revolve and propel the carriages forward, are connected together by a swivel kind of universal joint, which communicates the rotatory motion to each successive carriage, even if so placed on the curves of the roads, that the sides of one carriage shall present to the side of the next an angle of thirty degrees. To cause the carriage wheels to run round the curves of the rail-way, without the usual destructive rubbing of their surfaces, the rails in those parts are made with several ribs or elevations, and the wheels of the carriages are consequently formed to correspond with those ribs, by their peripheries being grooved in like

manner: so that a wheel, in effect, possesses as many diameters as there are variations in the surface of its periphery, by which means it may be made to travel faster or slower, as may be desired.

The annexed engravings will render Mr. James's plans intelligible to the reader.

a is the boiler of a steam engine; *b* the engine with two cylinders, the alternating motion of the piston in which gives rotation to the crank, *c*; above; the rods, *e e*, attached to the same, being also fixed to the crank of the horizontal shaft, *f f f*, (which passes under the carriages), causes that to revolve with a similar speed to the crank of the engine. Two square boxes, *g g*, are fixed under each carriage; through these the axletrees of each pair of wheels pass; the rotatory shaft, *f*, passes also through the boxes, above the axletrees, and at right angles with them; each of the boxes, *g g*, contain a double-bevelled horizontal wheel, which presents a circle of cogs in its upper as well as its lower side, and turns upon cross bearings; now the shaft *f*, carrying upon it a vertical bevelled pinion in each box, takes into the upper circle of teeth of the horizontal wheel, while the under circle of teeth of the same, actuate a bevelled pinion on the axletree underneath, consequently, compels the wheels to revolve; and the power being thus applied to every pair of wheels simultaneously, sufficient resistance is obtained, on a smooth surface, to ascend inclined planes of considerable elevation. *u u u u u*, are the universal joints, which communicate rotatory motion when the carriages are not in a straight line: these and other moving parts are distinctly shown in fig. 2, which is upon a larger scale.

f f is the rotatory shaft; *g g* the two boxes, with the front plates removed to show the gear inside; *h h* the bevelled pinions upon the shaft in each box; *i i* the horizontal double-bevelled wheels. The front box, *g*, under the carriage, is fixed immoveably to a solid block of wood, *k*; the other box is fixed to a plate *l*, turning on a central point, which passes through another plate, *m*, above, the latter being secured to the floor of the carriage by hinge-

W. H. James's Mode of Propelling Railway Carriages. 1823.

joints, *n n*. The construction of the universal joints *u u*, is also more clearly shewn in this figure.

We have now to describe the contrivances by which the patentee obviates the destructive effects of the rubbing or sliding of the inner wheels of carriages in making curves or turns in a round.

Our readers need not be informed, that if the wheels on one side of a carriage be larger, or of greater diameter, than those on the opposite side, such carriage, when propelled, will necessarily make a curve. On this principle, the patentee's contrivances are founded. In running along a straight line, the peripheries of the wheels are of equal elevation; but when the carriage has to make a turn, the wheels on one side roll on a greater diameter, or more extended periphery; while the wheels on the opposite side run on a less extended periphery, and the elevations upon the rails on which they run are so adjusted to these variations, that the different peripheries of the wheels change, and come in contact with the variable parts of the rail, and run round the curves, without any perceptible increase of friction, or jarring, or jolting. The annexed diagrams are in illustration of this part of the patentee's improvements.

In this figure, the carriage wheels are supposed to be running in a straight line, consequently the peripheries are equal, and the bearings of the rail equal.

In this figure, the wheels are supposed to be making a curve equal to an increase of half an inch in a yard on the outer line or track.

In this, the wheels and other parts are adapted to make a turn, where the curve makes a difference in the two lines of two-thirds of an inch in the yard.

In this, a curve wherein the difference is one inch.

Mr. James considers that the following advantages will result from these improvements, *viz.*

"A saving will be effected in the principal part of the cuttings, embankments, viaducts, &c., and a saving of full four-fifths of the time requisite for making the road. In saving the land lost in deep cutting, and the slopes of the embankments; and in shortening the distance, in consequence of the engine and loaded carriages being able to pass over elevated ground. Owing to the resistance at each individual carriage, the engine carriage may be reduced full one-third in weight, therefore a greater load may be propelled by the same power. In saving the primary and current expenses of fixed engines, wherein the power applied is always the same, whether the traffic upon the rail requires it or not, and in avoiding the delay consequent upon their employment; whereas, in locomotive engines the power may always be adapted to the trade or load. In affording the opportunity of passing over or under turnpike roads, &c. by which much of the objections raised against rail-ways in populous districts is obviated; and the facility with which obstacles in private property may be avoided. In enabling the engine and train of carriages to be suddenly stopped, whether on level ground or in descending hills. Likewise reducing the liability to breakage or accident in stopping such carriages, in consequence of the number of parts to resist a sudden impulse.

"Rail-roads of the usual construction soon get out of order by wearing at the turns, and in the settling of the ground in new embankments, which will be wholly prevented by the present improvements. There being no deep cuttings and embankments, property in land will not be divided by them, as in ordinary cases. By means of the joints (before mentioned) under each of the carriages, a nearly equal bearing of each wheel is effected, if the surface of the rails should be uneven, so as to cause the axles to stand at different angles. A considerable saving, it is considered, will likewise be made in the tonnage and interest of the capital expended, and in completing the rail in much less time than usual; also in the facility and

little expense attending the making alterations in the rail after completion."

Mr. W. H. James's mode of communicating the impulse of the prime mover to all the carriages of a train, seems to be well deserving of the attention of engineers; but we are apprehensive that his ingenious combinations for making turns in the road will not *wear* well in practice, and that the disadvantages of the increased weight of the wheels, and other obvious difficulties attending a permanent adjustment of the curved rails, will prevent their introduction. The inventor has, however, given the subject much of his attention, and it may be more valuable than we conjecture.

We have already noticed the immense extent to which rail-roads have been carried in various parts of the kingdom, and we conceive it to be now our duty to give a detailed account of that stupendous work, the Manchester and Liverpool Rail-way, celebrated for having called forth the talents of rival engineers to produce the best locomotive carriage, to be employed as a drag upon the rail-way. In that account, we purpose availing ourselves largely of the information afforded by Mr. Booth, in his interesting history of this rail-way, as the facts therein may be relied upon as authentic, owing to the official situation held by its talented author, (that of Treasurer to the company.)

In 1760, two thousand five hundred and sixty vessels paid dock duties at Liverpool; in 1824, ten thousand; and in 1829, eleven thousand three hundred and eighty three;—in 1760, the population of Liverpool was twenty-six thousand; in 1824, one hundred and thirty-five thousand; the population of Manchester being, in 1760, twenty-two thousand; in 1824, one hundred and thirty-five thousand;—in 1784, eight bags of cotton were imported into Liverpool from America; in 1824, four hundred and nine thousand, six hundred and seventy bags; and in 1829, six hundred and forty thousand, nine hundred and ninety-eight. In 1790, the first steam-engine was set up in

Manchester; in 1824, there were two hundred steam-engines there: in 1814, there was not one power-loom in Manchester; in 1824, there were thirty thousand. In 1824, the average quantity of raw and manufactured goods transmitted between the two towns was one thousand tons daily, and it now amounts to thirteen hundred tons; about one thousand of which pass from Liverpool to Manchester, and three hundred from Manchester to Liverpool. The bulk of this immense traffic was carried by means of two canals.

Goods had to be first sent up the river Mersey to Runcorn, a distance of about twenty miles, and thence by one of the two canals to Manchester, making the whole distance between the two towns about fifty miles. In summer time, there was frequently a deficiency of water, obliging boats to go only half loaded, while in winter, they were sometimes locked up with frost, for weeks together. Vessels, too, were often arrested in their progress up the Mersey, by contrary winds, and exposed to loss and damage from tempestuous weather. The *average* length of the passage was thirty-six hours; but, owing to the various causes of delay just enumerated, there have been instances of goods being a longer time on the way (by water) from Liverpool to Manchester, than from New York to Liverpool!

In 1824, Mr. Sanders, to whom the plan of a rail-way between the two towns had been suggested by Mr. William James, engineer, published a pamphlet in furtherance of the plan, in which he observes, "Notwithstanding all the accommodation the canals can offer, the delays are such that the spinners and dealers are frequently obliged to cart cotton on the public high-road, a distance of thirty-six miles, for which they pay four times the price which would be charged by a rail-road, and they are three times as long in getting it to hand. The same observation applies to manufactured goods, which are sent by land-carriage daily, and for which the rate paid is five times that to which they would be subject by the rail-road. This enormous sacrifice is made for two reasons; some-

times because conveyance by water cannot be promptly obtained, but more frequently because speed and certainty as to delivery are of the very first importance." About the same period, the following public declaration was signed by upwards of one hundred and fifty of the most respectable merchants of Liverpool.

"We, the undersigned merchants and brokers, resident in the port of Liverpool, do hereby declare, that we have for a long time past experienced great difficulty in obtaining vessels to convey goods from this place to Manchester, and that the delay is highly prejudicial to the trading and manufacturing interests at large; that we consider the present establishments for the transport of goods quite inadequate, and that a new line of conveyance has become absolutely necessary, to conduct the increasing trade of the country with speed, certainty, and economy."

It was accordingly determined to establish a company for the formation of a double rail-way from Liverpool to Manchester, and on the 29th of October, 1824, the first prospectus of the company was issued. The advantages promised by this prospectus, and in an amended one, afterwards substituted, were briefly these:—A saving of time and of money in the transmission of the thousand tons or more conveyed between the two towns daily; the increase of commerce and manufactures, by increased facility of intercourse; an improved channel for the conveyance of the manufactures and agricultural produce of Ireland to the populous counties of Lancaster and York; the carriage of farming produce to the large towns, and the return of lime, manure, &c. to the farmers; speedier conveyance for travellers; and the carriage of coals to Liverpool and Manchester, from the valuable mines in the vicinity of St. Helen's, the coals having been heretofore brought to Liverpool principally by canal, a distance of thirty miles, whilst by the rail-road the distance would be less than half, and the price materially reduced. The quantity of coals consumed annually in Liverpool and Manchester was estimated at one million of tons, and it

was calculated that the saving in the price of this necessary article of domestic consumption, would alone amount to at least two shillings per ton, or £100,000 annually, in the consumption of the two towns.

The rails used in this work are of the edge kind, such as we have described at page 570; they are made of wrought-iron, in lengths of five yards each, and weigh thirty-five pounds per yard. The rails are supported, every three feet, upon stone blocks, each block containing nearly four cubic feet of stone. Two holes, six inches deep and one inch diameter, are drilled into each block, and into these are driven oak plugs; and the cast-iron chairs, to which the rail is immediately fastened, are firmly spiked down to the oak plugs, forming altogether a construction of great solidity and strength. On the embankments, where the foundation may be expected to subside, the rails are laid on oak sleepers; thus there are thirteen miles of the rail resting on oak, and the remaining eighteen miles on stone sleepers. There are two double lines of rails (as represented in the preceding figure 7,) which, it is said, "are laid down with mathematical correctness," and there is reason to believe that great attention has been paid in the execution of this part of the work, the resistance to the motion of the carriages thereon having been found much less than any other rail-way of the same kind. The four rails are placed equidistantly, four feet eight inches apart; they are about two inches in breadth, and rise about one inch above the surface.

From Liverpool, the rail-way commences with the tunnel, one end of which is in Wapping, near the Queen's Dock, and extending under the town of Liverpool, nearly from west to east, to Edge Hill, a distance of rather more than a mile and a quarter. It was constructed in seven or eight separate lengths, each communicating with the surface by means of perpendicular shafts. The first two hundred and seventy yards from Wapping are perfectly level; in the remaining distance of one thousand nine hundred and eighty yards, there is a uniform rise of three-fourths of an inch in the yard, so that the mouth of the

tunnel at Edge Hill is one hundred and twenty-three feet higher than the Wapping end. The tunnel is white-washed throughout, and lighted with gas, and the effect produced is very singular and picturesque. The gas-lights, which depend from the roof, are thirty yards apart; those nearest the spectator appear at considerable distances from each other, but gradually approximating in the perspective, they finally become blended into a continuous and brilliant line of flame, fading away from a pure white to a fine red colour. The whitened roof and sides contiguous to each light are so strongly illumined, that the whole vista appears like a succession of superb arches formed through massive parallel walls, the intervening spaces being left in comparative darkness.*

About half a mile from the tunnel, the rail-road crosses Wavertree Lane, and there is then a descent, for five miles and a half, at the rate of one in eighteen hundred and twenty, or four feet in the mile. About half a mile to the north of Wavertree, at Olive Mount, there is an excavation through the solid rock, seventy feet below the surface, and two miles in length. The road is here little more than barely sufficient for two carriages to pass. The road is then carried, by means of a great embankment, varying from fifteen to forty-five feet in height, and from sixty to one hundred and thirty-five feet in breadth at the base, across a valley at Roby, or Broadgreen, two miles in length. It then crosses the Huyton turnpike road, a little past Roby; six miles and three quarters from Liverpool there is a junction rail-way, for the conveyance of coals from the neighbouring mines; on the right, and at a distance of seven or eight miles from the Liverpool station, it comes to the Whiston inclined plane, which is one mile and a half long, and rises about one in ninety-six. There is here a stationary engine to assist the carriages in their ascent. For nearly two miles, the road is then on an exact level. It was on this part of the road, that the contest of locomotive carriages, for the premium of £500,

* Walker's "Description of the Rail-way."

took place, in October last, the result of which determined the directors to make use of locomotive engines instead of stationary ones. About half a mile from the Whiston plane, at Rainhill, the Liverpool and Manchester turnpike-road crosses the rail-way, at an angle of thirty-four degrees. On leaving the level at Rainhill, the rail-way crosses the Sutton inclined plane, which is of the same extent as that at Whiston, and descends in the same proportion that the other rises. There is here another stationary engine. A little beyond Rainhill several collieries communicate with the road by means of rail-ways, and the Runcorn Gap Rail-way will here cross the line to St. Helen's.

The next object of interest is Parr Moss, the road over which is formed principally of the clay and stone dug out of the Sutton inclined plane, and extends about three quarters of a mile. The moss was originally about twenty feet deep, and the embankment across it is nearly twenty-five feet high, though only four or five feet now appear above the surface, the rest having sunk below it. The road is then carried over the valley of Sankey, by means of a massive and handsome viaduct, consisting of nine arches, of fifty feet span each; the height of the parapet being seventy feet above the Sankey canal in the valley beneath. The viaduct is built principally of brick, with stone facings, and the foundations rest on piles of from twenty to thirty feet in length, driven into the ground. The breadth of the rail-way between the parapets is twenty-five feet. The viaduct is approached by a stupendous embankment, formed principally of the clay dug from the high lands surrounding the valley. The appearance of the vessels sailing in the canal, seventy feet beneath the viaduct, has a romantic and striking effect. It is situated about fourteen miles and a half from Liverpool. The expense was £45,208 : 18 : 6. A little to the south of the town of Newton, the rail-way crosses a narrow valley, by the short but lofty embankment of Sandy Mains, and a handsome bridge of four arches, each forty feet span, under one of which passes the Newton and War-

rington turnpike-road. The Wigan and Newton branch here enters the rail-way.

A few miles beyond Newton is the great Kenyon excavation, from which, above eight thousand cubic yards of clay and sand were dug out. The Kenyon and Leigh Junction Rail-way here joins the Liverpool and Manchester line, and, as it also joins the Bolton and Leigh line, brings into a direct communication Liverpool and Bolton. The Liverpool and Manchester Railway then passes successively under three handsome bridges; and a little beyond Culcheth, over the Brosely embankment, which is about a mile and a half in length, and from eighteen to twenty feet in height. It then passes over Bury Lane, and the small river Gless, or Glazebrook, and arrives at Chat Moss. This is a huge bog, comprising an area of about twelve square miles, so soft that cattle cannot walk over it, and in many parts so fluid, that an iron rod laid upon the surface would sink to the bottom, by the effect of its own gravity. It is from ten to thirty-five feet deep, and the bottom is composed of clay and sand. It was accounted by some an impossibility to carry the road across this huge bog; but, by ingenuity and perseverance, the work has been effected, and a firm road is now carried across the moss. Hurdles of brushwood and heath are placed under the wooden sleepers, supporting the rails over the greatest part of the moss, and the road may be said to float on the surface. The most difficult part was on the eastern border, extending about half a mile, where an embankment of twenty feet in height was made, and many thousand cubic feet of earth sank into the moss and disappeared, before the line of road approached the proposed level. At length, however, it became consolidated; in 1829, one rail-way was laid over the whole moss, and on the first of January, 1830, the Rocket steam engine, with a carriage and passengers, passed over it. The line extends across the moss a distance of about four miles and three quarters, and the road is not inferior to any other part of the rail-way. The work was completed at an expense of £27,719 : 11 : 10.

On leaving Chat Moss, the road passes over the lowlands at Barton, extending about a mile between the moss and Worsley canal, by means of an embankment; it is carried over the canal by a neat stone viaduct of two arches; it then proceeds through Eccles, and a portion of Salford, under six bridges; it is carried over the Irwell by a handsome stone bridge, of sixty-three feet span, thirty feet from the water, and then over twenty-two brick arches; and a bridge over Water Street, to the Company's station in Water Street, Manchester, a distance of thirty-one miles from the Liverpool station. The rail-way is there on a level with the second story of the Company's warehouses. On the line between Liverpool and Manchester, there are, besides culverts and foot bridges, sixty-three bridges, of which thirty pass under the turnpike-road, twenty-eight over it, four over brooks, &c., and one over the river Irwell. There are twenty-two of brick, seventeen of wood and brick, eleven of brick and stone, eleven of wood, and two of stone and wood, at a total expense of £99,065 : 11 : 9.

From the top of the Liverpool tunnel to Manchester, with the exception of two inclined planes at Rainhill, (one ascending and the other descending, at an inclination of one in ninety-six, and where some assistant power must be used) there is no greater inclination than in the ratio of about one in eight hundred and thirty; and since the advantage on the descending side will nearly counterbalance the disadvantage in ascending so gradual a slope, the rail-way may be regarded, for practical purposes, as nearly horizontal. The rails at the mouth of the tunnel, at Edge-hill, are forty-six feet above the rails at the Manchester end of the line.

In the formation of the rail-way, there have been dug out of the different excavations, upwards of three millions of cubic yards of stone, clay, and soil; and the weight of the double lines of rail laid down, is more than four thousand tons.

The following general abstract of the expenditure of the rail-way, to the thirty-first of May, 1830, showing the

cost of the different branches of the undertaking, may be of considerable use to those who shall hereinafter embark in similar adventures.

Advertising account				£332	1	4
Brick-making account				9,724	4	4
Bridge account				99,065	11	9
Charge for direction				1,911	0	0
Charge for fencing				10,202	16	5
Cart establishment				461	6	3
Chat Moss account*				27,719	11	10
Cuttings and embankments†				199,763	8	0
Carrying department, comprising account expended in land and buildings for stations and depôts, warehouses, offices, &c., at the Liverpool end	£35,538	0	0			
Expended at the Manchester station	6,159	0	0			
Side tunnel	2,485	0	0			
Gas-light account, including cost of pipes, gasometer, &c.	1,046	0	0			
Engines, coaches, machines, &c.	10,991	11	4			
				56,219	11	4
Carried forward				£405,399	11	3

* The embankments included under this head consist of about two hundred and seventy-seven thousand cubic yards of raw moss earth, in the formation of which, about six hundred and seventy-seven thousand cubic yards of raw moss have been used; the difference in measurement being occasioned by the squeezing out of the superabundant water, and consequent consolidation of the moss. The expenditure on this part of the line has been less than the average expenditure.

† Under this head is comprised the earth work on the whole line, exclusive of the Chat Moss district. The cuttings somewhat exceed the embankings; the surplus is principally deposited along the border of the Great Kenyon Cutting. The excavations consist of about seven hundred and twenty-two thousand cubic yards of rock and shole, and about two million six thousand cubic yards of marl, earth, and sand. This aggregate mass has been removed to various distances, from a few furlongs to between three and four miles; and no inconsiderable portion of it has been hoisted up by machinery, from a depth of thirty to sixty feet, to be deposited on the surface above, either to remain in permanent spoil banks, or to be afterwards carried to the next embankment.

Brought forward				£405,399	11	3
Formation of the road*				20,568	15	5
Rail account				67,912	0	0
This expenditure comprises the following items:—						
Rails for a double way from Liverpool to Manchester, with occasional lines of communication, and additional side-lines at the different depôts, being about thirty-five miles of double way = three thousand eight hundred and forty-seven tons, at prices averaging something less than £12 : 10*s.* per ton	48,000	0	0			
Cast-iron chains, one thousand four hundred and twenty-eight tons, at an average of £10 : 10*s.*	15,000	0	0			
Spikes and keys to fasten the chains to the blocks, and the rails to the chains....	3,830	0	0			
Oak plugs for the blocks	615	0	0			
Sundry freights, cartages, &c.	467	0	0			
Interest account (balance)				3,629	16	7
Land account				95,305	8	8
Office establishment				4,929	8	7
Parliamentary and law expenditure				28,465	6	11
Stone blocks and sleepers†				20,520	14	5
Surveying account				19,829	8	7
Travelling account				1,423	1	5
Tunnel account..				34,791	4	9
Tunnel compensation account				9,997	5	7
Waggons used in the progress of the work				24,185	5	7
Sundry payments for timber, iron, petty disbursements, &c.				2,227	17	3
				£739,185	5	0

* By this is understood what is termed ballasting the road—that is, depositing a layer of broken rock and sand, about two feet thick, viz. one foot below the blocks, and one foot distributed *between* them, serving to keep them firm in their places. Spiking down the iron chains to the blocks or sleepers, fastening the rails to the chains with iron keys, and adjusting the rail-way to the exact width, and curve, and level, come under this head of expenditure.

† Out of thirty-one miles, eighteen are laid with stone blocks, and thirteen with wooden sleepers or larch; the latter being laid principally across the embankment and across the two districts of moss

The directors, in their report of March last, state, that, for the finishing the work, wallings, fencings, warehouses, &c. a further sum of £80,834 : 15*s*. will be necessary; thus making the whole sum expended in this magnificent and national undertaking, £820,000, or more than double the estimate made in the first prospectus of the company.

It appears that the directors had considerable difficulty in coming to a conclusion respecting the kind of *carriage* to be used, and the *power* to be employed. On this part of the subject, Mr. Booth observes:—

"Multifarious were the schemes proposed to the directors for facilitating locomotion. Communications were received from all classes of persons, each recommending an improved power, or an improved carriage; from professors of philosophy, down to the humblest mechanic, all were zealous in their proffers of assistance. England, America, and continental Europe, were alike tributary. Every element, and almost every substance, was brought into requisition, and made subservient to the great work. The friction of the carriages was to be reduced so low, that a silk thread would draw them, and the power to be applied was so vast as to rend a cable asunder. Hydrogen gas and high-pressure steam, columns of water and columns of mercury, a hundred atmospheres and a perfect vacuum, machines working in a circle without fire or steam, generating power at one end of the process and giving it out at the other, carriages that conveyed every one its own rail-way, wheels within wheels to multiply and feed without diminishing power; with every complication of balancing and countervailing forces, to the *ne plus ultra* of perpetual motion. Every scheme which the restless ingenuity or prolific imagination of man could devise, was liberally offered to the company,—the difficulty was, to choose and to decide.

"Was a capital of £100,000 to be invested in *stationary engines*, or in *locomotives?* The directors resolved to obtain the assistance of two professional engineers, who should visit the Darlington and Newcastle rail-ways, the great theatre of practical operations, carefully examine

the working of the two species of mechanical power, taking note of the advantages and disadvantages of each, make an accurate calculation of the *cost* of both modes of conveyance, and report to the Board fully on the subject." This was accordingly done, and the reports of the comparative merits of the two modes were laid before the committee.

The leaning on the part of a majority of the directors was in favour of locomotives, provided they could be constructed of adequate power, and at a less weight than the travelling engines then in use, which were generally eight or nine tons in weight, and some still heavier, the consequence of which was, no small injury to the rail-ways, and proportionate expense in keeping the road in repair: and further, it was quite essential, according to the provisions of the Rail-way Act, that they should not *smoke*. The directors determined to obtain, if possible, a locomotive engine of improved construction, that should comply with these conditions; and with that object in view, publicly offered a reward for the most improved locomotive engine, subject to certain stipulations and conditions, a copy of which is subjoined.

"*Rail-way Office, Liverpool,*
25th April, 1829.

"Stipulations and Conditions

"On which the directors of the Liverpool and Manchester Rail-way offer a premium of £500, for the most improved locomotive engine.

"1. The said engine must 'effectually consume its own smoke,' according to the provisions of the Rail-way Act, 7th Geo. IV.

"2. The engine, if it weighs six tons, must be capable of drawing after it, day by day, on a well-constructed rail-way, on a level plane, a train of carriages, of the gross weight of twenty tons, including the tender and water-tank, at the rate of ten miles an hour, with a pressure of

steam in the boiler not exceeding fifty pounds on the square inch.

"3. There must be two safety-valves, one of which must be completely out of the reach or controul of the engine-man, and neither of which must be fastened down while the engine is working.

"4. The engine and boiler must be supported on springs, and rest on six wheels; and the height, from the ground to the top of the chimney, must not exceed fifteen feet.

"5. The weight of the machine, *with its complement of water* in the boiler, must, at most, not exceed six tons; and a machine of less weight will be preferred, if it draw *after* it a *proportionate* weight; and if the weight of the engine, &c. do not exceed *five tons*, then the gross weight to be drawn need not exceed fifteen tons, and in that proportion for machines of still smaller weight, provided that the engine, &c. shall still be on six wheels, unless the weight (as above) be reduced to four tons and a half, or under, in which case the boiler, &c. may be placed on four wheels. And the company shall be at liberty to put the boiler, fire-tube, cylinders, &c. to the test of a pressure of water not exceeding one hundred and fifty pounds per square inch, without being answerable for any damage the machine may receive in consequence.

"6. There must be a mercurial guage affixed to the machine, with index rod, showing the steam pressure above forty-five pounds per square inch, and constructed to blow out a pressure of sixty pounds per inch.

"7. The engine to be delivered complete for trial, at the Liverpool end of the rail-way, not later than the 1st of October next.

"8. The price of the engine which may be accepted, not to exceed £550, delivered on the rail-way; and any engine not approved, to be taken back by the owner.

"N.B. The rail-way company will provide the *engine tender* with a supply of water and fuel for the experiment. The distance within the rails is four feet eight inches and a half."

Meanwhile, all measures relative to the moving power were suspended, till the result of the trials of the specimen engines should be ascertained. On the 6th of October, which was the day subsequently fixed for the trials, the judges appointed by the company, on considering the card of "stipulations and conditions" originally issued by the directors, found it necessary to make the following arrangements for the trial, which we insert, as some of the conditions embrace a very correct mode of testing the power of such machines.

"TRIAL OF THE LOCOMOTIVE ENGINES ON THE LIVERPOOL AND MANCHESTER RAIL-WAY.

"The following is the ordeal which we have decided each locomotive engine shall undergo, in contending for the premium of £500, at Rainhill.

"The weight of the locomotive engine, with its full complement of water in the boiler, shall be ascertained at the weighing-machine, by eight o'clock in the morning, and the load assigned to it shall be three times the weight thereof. The water in the boiler shall be cold, and there shall be no fuel in the fire-place. As much fuel shall be weighed, and as much water shall be measured and delivered into the tender carriage, as the owner of the engine may consider sufficient for the supply of the engine for a journey of thirty-five miles. The fire in the boiler shall then be lighted, and the quantity of fuel consumed for getting up the steam shall be determined, and the time noted.

"The tender carriage, with the fuel and water, shall be considered to be, and taken as part of the load assigned to the engine.

"Those engines which carry their own fuel and water, shall be allowed a proportionate deduction from their load, according to the weight of the engine.

"The engine, with the carriages attached to it, shall be run by hand up to the starting-post; and as soon as the

steam is got up to fifty pounds per square inch, the engine shall set out upon its journey.

"The distance the engine shall perform each trip, shall be one mile and three quarters each way, including one eighth of a mile at each end, one for getting up the speed, and the other for stopping the train; by this means, the engine, with its load, will travel one mile and a half each way, at full speed.

"The engine shall make ten trips, which shall be equal to a journey of thirty-five miles; thirty miles whereof shall be performed at full speed, and the average rate of travelling shall not be less than ten miles an hour.

"As soon as the engine has performed this task (which will be equal to the travelling from Liverpool to Manchester,) there shall be a fresh supply of fuel and water delivered to her; and as soon as she can be got ready to set out again, she shall go up to the starting-post, and make ten trips more, which will be equal to the journey from Manchester back again to Liverpool.

"The time of performing every trip shall be accurately noted, as well as the time occupied in getting ready to set out on the second journey.

"Should the engine not be enabled to take along with it sufficient fuel and water for the journey of ten trips, the time occupied in taking in a fresh supply of fuel and water, shall be considered, and taken as a part of the time in performing the journey.

"J. U. Rastrick, Esq. Stourbridge, C. E.
"Nich^s. Wood, Esq. Killingworth, C. E. } Judges.
"John Kennedy, Esq. Manchester.

"*Liverpool, Oct.* 6, 1829."

The number of competitors actually ready to take the field were only five, although several other individuals had made preparations for that purpose, but were not ready in time. The following is a list of those which experimented:—

No. 1. Messrs. Braithwaite and Ericsson, of London, "The Novelty;" weight, 2 tons, 15 cwt.

No. 2. Mr. Timothy Hackworth, of Darlington, "The Sans Pareil;' weight, 4 tons, 8 cwt., 2 qrs.

No. 3. Mr. Robert Stephenson, of Newcastle-upon-Tyne, "The Rocket;" weight, 4 tons, 3 cwt.

No. 4. Mr. Brandreth, of Liverpool, "The Cyclopede;" weight, 3 tons, worked by a horse.

No. 5. Mr. Burstall, of Edinburgh, "The Perseverance;" weight, 2 tons, 17 cwt.

Stephenson's Locomotive Rail-way Carriage. 1829.

On the 6th, the first engine which experimented was "The Rocket" of Mr. Stephenson, an external view of which is represented in the preceding cut.

Its construction has been thus described in a periodical journal:—"The furnace, A, is two feet wide, by three feet high; the boiler, B, is six feet long, and three feet in diameter. The furnace has an external casing, between which and the fire-place there is a space of three inches, filled with water, and communicating with the boiler. The heated air from the furnace is circulated through the boiler by means of twenty-five copper pipes, of three inches each in diameter, which have their termination in the tall chimney C. P G, are safety valves; H H, the steam eduction pipes; D, one of two steam cylinders, which are placed in an inclined position, and embrace, like two arms, the boiler between them. E, one of the connecting rods, which give motion to the wheels; *a*, the slide-valves; and *o*, one of two escape-pipes. M is part of the tender appropriated to the carriage of the fuel; N, the water cask."

From this description of Mr. Stephenson's machine, it is evidently capable of affording considerable power. A load was attached to it, of twelve tons, fifteen hundred weight, which it drew at the rate of from ten to eleven miles in the hour, and when the weight was detached from it, it attained a speed of about eighteen miles in the hour. This experiment, it would appear, was only intended as a rehearsal, and not as a decisive trial of its powers, as it was afterwards proved capable of producing more than double that effect, as we shall hereafter describe, in its proper place.

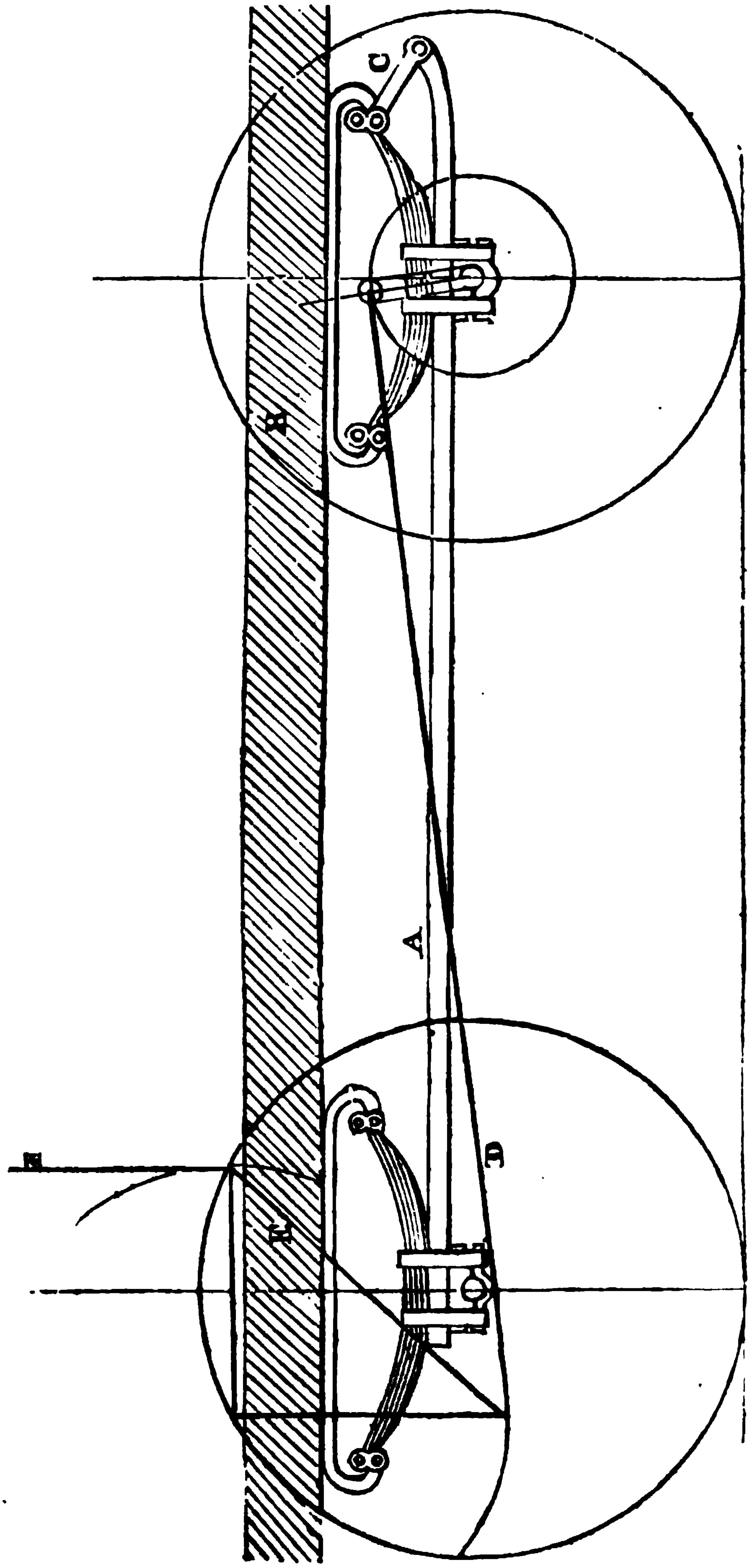
The next engine that exhibited its locomotive power was "The Novelty," of Messrs. Braithwaite and Ericsson, which was much admired for its lightness and compactness; the form being also very different to that of all other locomotives previously used, and the beauty or superior finish of its workmanship, made it an object of great attraction. In the annexed cut, a side elevation of it is given.

Braithwaite and Ericsson's Rail-way Carriage. 1829.

The preceding engraving, fig. 1, exhibits an external elevation of the machine. F, is the carriage-frame; E, one end of a long horizontal cylinder, forming the principal part of the boiler, which extends to the large vertical vessel A, at the other end of the carriage, and contains forty-five gallons of water; L, a hopper, to supply the fuel, (which is carried in small baskets placed on the carriage,) whence it is conducted by a tube in the centre of the steam-chamber A, into the furnace S, beneath. At C, is a blowing machine, the air from which is conducted by a pipe under the carriage, and proceeding by the tube K, enters the ash-pit M, under the furnace; Q, is a pipe for the escape of the heated gases after the combustion, and forms the only chimney used; B, is the water-tank; at D N are two working cylinders, with their steam-pipes and valves; the cylinders are six inches in diameter, and have a twelve-inch stroke; O G are connecting rods, which impart the force of the engines to the running wheels; the arrangement of these parts will be better comprehended by the annexed diagram, fig. 2.

The axletrees are fixed to an iron rod A, and slings are introduced at C, to prevent, it is said, the side action between the rod and the carriage-frame B; and to prevent the effect of the springs from counteracting the action of the engine, the connecting rods at D are placed, as nearly as possible, in a horizontal position, and the motion is communicated to them by bell-cranks at E, on each side of the carriage, being connected by the slings F, to the piston rods. The pistons used are the patent metallic of Barton, (described at page 427,) and the running wheels, the patent suspension kind, of Theodore Jones and Co. (See *Journal of Patent Inventions*, vol. ii. page 65.)

Fig. 3, exhibits a section of the boiler introduced by Messrs. Braithwaite and Ericsson, into "The Novelty" steam-carriage, which we are induced to insert here, as it has been deemed, by some *influential* persons, to be the grand *desideratum* in this branch of practical mechanics; it is, therefore, desirable that its real merits should come under the consideration of the reader.



(FIG. 2.)

(FIG. 8.)

S, is the furnace surrounded by water, and L, the tube by which the fuel is supplied to feed the fire; M, is the ash-pit, through which the air is forced by the pipe K, from the bellows of the engine. The vessel containing the water that surrounds the furnace, and the long cylinder that proceeds horizontally from it, constitute the boiler, as shown at E E e. The flames and heated air from the furnace, after ascending by the action of the bellows, enter a long tortuous flue, which makes three turns in the entire length of the horizontal boiler, escaping finally at the chimney. The fuel in the furnace has, therefore, a direct action upon the water surrounding it, and the water in the long cylinder is operated upon by the gases in the flue, which gradually tapers from the furnace to the chimney, and has a constant inclination downward. This part of the arrangement seems to be good, as affording convenient means of cleansing the flues of any soot that may deposit itself in them, which, it is presumed, may be performed at any time, by an energetic application of the blowing machine; and as the whole of the furnace and flues is surrounded by the water of the boiler, there can evidently be very little of the heat from the fuel misapplied. Notwithstanding these important advantages, we are inclined to believe that the boiler will not stand the test of experience; we suspect that the boiler will be

frequently "burnt out," in those places where a sudden turn in the flue causes the air to impinge in greater quantity or force than on the surrounding portions. Several failures of the boiler have already taken place near the flange *a*, where the ascending current of the concentrated heat of the furnace first impinges with great force. Should the pumps happen to fail temporarily in supplying the requisite quantity of water, (which is not of unfrequent occurrence,) and that part of the boiler become uncovered with the fluid, it would instantly be made red hot, and a renewed supply of water afterwards would almost infallibly cause a violent explosion of the boiler, by the sudden generation of very high steam. The great steam chamber A, is also a source of great danger, by its incapacity to withstand any sudden increase of force. Indeed, we are of opinion that all boilers having large steam chambers exposed to great variations of temperature and the force of steam, are unsuited to high-pressure engines, and especially those employed for locomotive purposes, for evident reasons.

In the first experiment made with this engine, no load was attached to it, and it is stated to have darted off at a velocity of twenty-eight miles per hour, and that one mile was performed in the space of one minute and fifty-three seconds. Such an unexpected and extraordinary velocity seemed to promise ultimate success in obtaining the prize, but the final result proved otherwise, by the engine being put out of order in the effort. On the following day, "The Novelty" was tried with three times its own weight attached, which, it is said, it drew at the rate of twenty miles and a half per hour; but the authenticity of this statement appears very doubtful, by its emanating from a partisan, and being unaccompanied by any particulars as to time and distance.

On the third day (Oct. 8) of the contest, "The Rocket" of Mr. Stephenson was tried in the precise manner directed by the judges in the "ordeal," quoted at page 606, and it was understood that this trial should be considered decisive of its merits.

The engine, with its complement of water in the boiler, weighing four tons five hundred weight, had her load attached to it of twelve tons fifteen hundred weight, making, with the persons who rode, upwards of seventeen tons. The journey was one mile and a half each way, with an additional length of two hundred and twenty yards at each end, to stop the engine, or to get up the speed. The first experiment was for thirty-five miles, or twenty such trips of one mile and three quarters each, which "The Rocket" performed, including all the stoppages, in three hours and ten minutes, which was upwards of eleven miles per hour. After this, a fresh supply of water was taken in, which occupied sixteen minutes, when the engine again started, and ran the thirty-five miles, including all stoppages, in two hours and fifty-two minutes, which is upwards of twelve miles in an hour, including all stoppages. The speed of the engine over the ground, with the prescribed load, was frequently eighteen miles per hour, and occasionally upwards of twenty. The whole performance was considerably greater than was required by the stipulations, or than had hitherto been accomplished by a locomotive engine.

"The Novelty" was the next engine that undertook the appointed task, but owing to some derangement having occurred in her machinery, she was obliged to stop almost at the commencement of the task assigned.

On the 9th of October (fourth day of the contest), a public notice appeared from Messrs. Braithwaite and Ericsson, stating, that *in consequence* of the alterations made in the conditions of the competition, the trial of their engine in the manner prescribed by the new "ordeal" had, with the approbation of the judges, been deferred to the following day: no trial, therefore, took place on that day. This indulgence to Messrs. Braithwaite and Ericsson, on the part of the judges, was polite and liberal, and evinced a spirit of fairness which nothing could gainsay; for it must be evident to every body who reads the "ordeal" in question, that the terms of it could form no ground of excuse for deferring the trial, and we

may hence infer the probability of the machinery of "The Novelty" having been out of order.

On the 10th of October (the fifth day of the contest), "The Novelty" was again weighed, and its load assigned. The steam was got up in fifty-four minutes from the time of lighting the fire, when, upon starting on the first trip, something gave way, which it was necessary to have repaired; this was done in the course of the day, and during the time so occupied, Mr. Stephenson's engine, "The Rocket," without any of the train or the tender, was run twice down the course and back, making seven miles. Thus "stripped for the race," "The Rocket" performed the seven miles, including the stoppages at each of the four trips, in the short period of fourteen minutes and fourteen seconds, which is at the rate of thirty miles the hour; and making allowance for the stoppages, the seven miles may be considered to have been performed at the rate of at least thirty-five miles the hour, which is much more than any performances, even for a shorter period, by any other carriage.

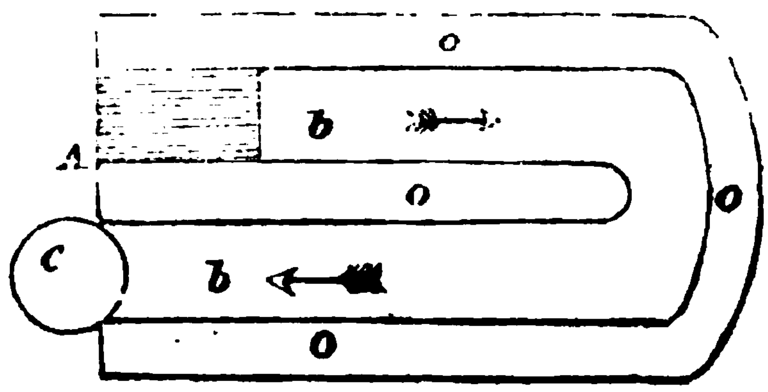
After this extraordinary performance, Messrs. Braithwaite and Ericsson exercised their carriage for the gratification of the spectators, who were extremely numerous, and not (as they stated) with a view to a decisive exhibition of its powers; but the utmost velocity "The Novelty" attained, *without* stoppages, fell very far short of the speed exhibited by "The Rocket," *including* stoppages.

On the sixth day of the contest (Oct. 13), Mr. Hackworth's engine, "The Sans Pareil," was pronounced to be ready for the "ordeal." On weighing it, it was found to exceed the weight of six tons, limited in the published "stipulations and conditions;" it could not, under this circumstance, become entitled to the prize, even if its performance should exceed the others in its experimental trials, but it was allowed to undertake the seventy miles, with three times its weight attached to it. It soon became manifest that the engine was of a very efficient kind. For two hours, "The Sans Pareil" kept going with great regularity, with its prodigious load of twenty-five tons

altogether, and in that time performed twenty-five miles, including all stoppages at the ends of the line, which was at the rate of twelve miles and a half per hour. In the middle of the line, when its average speed was obtained, the performance was at the rate of about fifteen miles the hour. While thus proceeding so satisfactorily, one of the feed-pipes burst, which rendered it incapable of proceeding.

Mr. Hackworth's Loco-motive Steam Engine. 1829.

The engraving represents a side elevation of the engine and its tender, on the scale of a quarter of an inch to the foot, which is the same as "The Rocket." The arrangement of the furnace, boiler, and flue, is shewn in the subjoined diagram;



a being the furnace, *b b* the flue, or tube, through the boiler, and *c* the chimney. The boiler is of the kind patented by Trevithick, as far back as 1804, and is unquestionably calculated to economise heat, as the furnace and flue are completely surrounded by the water in the boiler, as represented at *o o o.o*. D represents one of the two working cylinders, the pistons of which act, through the medium of connecting rods (which operate as cranks), upon the hind pair of the running wheels; and the motion of the latter is communicated to the fore wheels by horizontal connecting rods E, causing both pair of wheels to revolve together, by the direct power of the engine; G is a pipe for conveying the waste steam into the chimney. The mode of communicating the power of the engine to both pair of wheels, must, we think, be attended with the important advantage of obtaining more adhesion to the rails, and consequently of enabling it to draw a greater load.

On the 7th day, it was appointed that a decisive trial should be made of "The Novelty," which had been repeatedly deferred, owing to the derangement of some part of the machinery. It was stated, on the part of Messrs. Braithwaite and Ericsson, that a fresh pipe had been substituted for the one which failed on the preceding trial; and "one or two other parts of the machinery, that were in a faulty state, had been renovated;" but the engine, with the exception of some of the flanges of the boiler

being rather *green*, was pronounced in a working state. The load assigned to it by the judges was thus calculated:—

	tons.	cwt.	qrs.	lbs
Weight of the engine, without any water or fuel	2	15	0	0
Deduct for weight of tank and coke baskets, and the quantity of water and fuel deemed necessary for a journey of thirty-five miles	0	16	1	9
Net weight of the Novelty's working power, exclusive of the water, fuel, tank, &c.	1	18	2	19
× by				3
Given weight to be drawn, dropping the fractional parts	5	16	0	0

The engine now started to perform the seventy miles for a continuance ; but, just as it had completed its second trip of three miles, another derangement of the boiler took place, which obliged it to stop ; and it becoming evident to the proprietors that the machinery of "The Novelty" was too inefficient to proceed in the contest, they gave notice to the judges that they would withdraw their engine from any further trial, and leave it to be judged by the performances it had already exhibited.

After this occurrence, Mr. Burstall's engine, "The Perseverance" which had met with some injury in its journey from Edinburgh to Liverpool, but had been since repaired, was put to the "ordeal ;" but the utmost speed it attained was not more than five or six miles an hour, owing to some derangement of its parts. The mechanical combinations in the machine are nearly similar to that described at page 522.

The course was thus left clear to Mr. Stephenson, to receive the fairly-won prize of £500, for the production of the best locomotive steam engine hitherto constructed for railways. The intrinsic value of the prize is, however, of trifling consideration, when compared with that of establishing his reputation as an engineer on such a high and firm basis. The orders for all or the greater part of the engines, he will necessarily execute, and most likely, by his experience and talent, continue to improve them, so as to take the lead in this important branch of mechanics.

In the list of the rival machines given at page 113, is included the "Cyclopede," constructed by Mr. Brandreth, of Liverpool; but, on account of its not being propelled by the power mentioned in the "stipulations and conditions," it could not be considered as entering the lists for the prize therein proposed; it was, however, an inquiry well worth the investigation, what degree of power horses could exert, in a locomotive machine of the kind, and thereby determine its comparative economy, with that of steam. The inventor, Mr. Thomas Shaw Brandreth, of Liverpool, barrister-at-law, took out a patent for this machine, on the 9th of September, 1829; a side elevation and plan of which are given in the subjoined figures.

(FIG. 1.)

(*Brandreth's Patent Cyclopede.* 1829.)

(FIG. 2.)

It consists in an endless chain *a a a*, made of planks, about an inch and a half thick, and four inches wide, extending across the bed of the carriage, attached at their extremities to ropes, and carried over a drum *b b*, at each end of the carriage, as shewn in the plan at fig. 2. To strengthen these cross pieces, and to prevent one of them from slipping down by itself, a cleat *c c*, is nailed on the end of each, and extends half way across those next to it on each side; the position of these, as they pass over the drums *b b*, will best show their extent and attachments. The chain platform is supported on a series of anti-friction rollers *e e e e*. The horse is yoked to the frame, and by treading on the moveable platform, drives it round, by which the drums *b b*, are made to revolve, and through the medium of the spur wheels, shewn in the plan, puts in motion the carriage wheels. Two sets of spur gear are provided, one at each end of the drum, so that either may be put in action at pleasure, and be adjusted according to the nature of the road, whether in ascents, descents, or on horizontal planes, the speed or power being duly proportioned to the plane operated upon; *r a* represent the rope which is attached to the endless chain, and *w w*, the rail-way.

It will be observed that by this arrangement the horse employed to propel the carriage is carried along with it, and thus a velocity of motion is produced in the machine, far beyond the limits at which a horse can exert his power. Now as it has been ascertained that the resistance from friction on a level railway does not increase with an increase of speed, it follows that in many cases much advantage might be obtained, by an increase of velocity greatly exceeding that at which a horse could exert his power, *or even travel on the road, without exerting any power of traction.* The principal objection raised against this plan, is, that the horse has to carry his own weight; but this objection equally applies to the locomotive steam engine. "The Cyclopede" weighed three tons, of which the horse probably made half a ton; therefore, one-horse power weighs half a ton. "The Sans Pareil" weighed six tons, from which if we deduct two tons for the weight of the

carriage frame and wheels, it leaves four tons for the engine, boiler, water, fuel, &c. which must be pretty near the truth; therefore, if the steam power produced in the Sans Pareil was not more than equivalent to the force of traction of eight horses, no advantage was gained thereby; unless it can be shewn that the cost of fuel, the wear and tear of machinery, interest of money of first cost, &c. of the Sans Pareil, was not eight times the cost of the keeping the horse, &c. of the Cyclopede. The next point of inquiry seems to be, whether the Sans Pareil did exert a power of more than eight horses, in drawing twenty-five tons weight along the rail-way. To ascertain this fact, the resistance of the rail-way to the load moving thereon must be known; without a knowledge of which, it would be useless to enter into the inquiry. In the absence of correct data, we are inclined to believe that not four horses' power was exhibited by "The Sans Pareil," and consequently that the application of horse power, in the manner proposed by Mr. Brandreth, is well deserving of a careful trial.

The trial made on the Liverpool Railway, with this machine, was however far from successful; a speed of only five or six miles an hour being obtained; an eye-witness informs us that "the principle had not fair play," that "the apparatus was of very rude construction," and the horses (two being employed with two endless chains, and not one, as before described,) had not room to exert themselves, owing to the stalls in which they worked being made too small. We are far from thinking that a very convenient and useful machine may not be made on the principle herein developed.

Another method of employing the power of horses, in moving rail-way carriages, in which the animal giving the power was supported, was invented by Mr. Snowden, about five years ago, which we shall describe, after having concluded our account of the Manchester and Liverpool Rail-way.

"The peculiarity of the exhibition in the several days of trial," (Mr. Booth observes), "attracted a large concourse of spectators, and the unexampled speed of the Novelty

and the Rocket, excited universal surprise and admiration.

"The trial of these engines, (he continues) may be regarded as constituting a new epoch in the progress of mechanical science, as relating to locomotion. The most sanguine advocates of travelling engines had not anticipated a speed of more than ten or twelve miles per hour. It was altogether a new spectacle, to behold a carriage crowded with company, attached to a self-moving machine, and whirled along at the rate of thirty miles per hour."

Extraordinary and brilliant as the results undoubtedly were, there is not, we think, any just cause for surprise, in the power of the engines, which at most did not exceed four horses; the velocity acquired may rather be attributed to the excellence of the railway, which requires so small a comparative force, to move a given weight thereon. Greater velocity of motion than that obtained is scarcely desirable, but we make no doubt that ere long such improvements will be made in the engines, tending to reduce the friction of the moving parts, augment the production of steam, and apply it more economically, that the effective power hitherto exhibited will be considerably increased. A limit to the power of draught, obtained by the force of the engine, is made by the want of adhesiveness of the wheels of the engine carriage to the railway; and this limit cannot be extended without increasing the weight of the engine carriage; unless, indeed, the railway company were to introduce Mr. W. H. James's plan of communicating the power of the engine to some of the carriages of the train, described at page 588. A great advantage would, we think, result from the application of Mr. James's apparatus, as that would save the rails from being partially and injuriously loaded with unnecessarily heavy and cumbersome engines.

The question between locomotive and fixed engines was practically settled by the trials at Rainhill. The fitness of locomotives for travelling at almost any speed that could be desired, was strikingly exemplified; and the importance of this circumstance was duly estimated, the

conveyance of passengers between Liverpool and Manchester, having long been considered a valuable branch of the undertaking. There still remained one point to be settled, *viz.* the kind of power to be employed in ascending the inclined planes of Whiston and Sutton. These planes are each a mile and a half long, with an inclination of three eighths of an inch to the yard, being a rise of one in ninety-six. Stationary engines on the summit, with ropes passing over sheaves or pulleys along the whole ascent, are the means resorted to, at the inclined plane in the Liverpool Tunnel, also on the Darlington inclined planes, and at the Collieries in the North. It was quite evident, however, that such a plan of operations, in the centre of the Liverpool and Manchester line, with the interruption to be expected from a *change* in the moving power, to say nothing of the danger always to be apprehended from a system of ropes and pulleys, was to be avoided, if possible. It became an object, therefore, of no small interest, to ascertain the power of the new locomotives on the planes in question; and in the first place, as the effective power of the engine is necessarily limited by the adhesion of the wheels on the rails, (inasmuch as if a force be exerted beyond that point, the wheels will turn round, while the carriage will remain stationary,) it was important to know whether this difficulty was likely to occur on the planes in question. It has been ascertained that the adhesion of the engine wheels (as now constructed with wrought-iron tires) on wrought-iron rails, is equal to one-twentieth of the weight of the machine, in the most unfavourable state of the rails. If the engine weigh four tons and a half, the adhesion on the four wheels would be one-twentieth of that weight, or about five hundred pounds; or supposing, which is frequently the case, that the machinery is only connected with two wheels, then, if the weight be equally divided, the adhesion will be two hundred and fifty pounds; which, multiplied by two hundred, the *friction* being only one-two hundreth of the *gravity* of the load, commensurate with the adhesion, in the most favourable state of the rails, about forty tons being the adhesive load in an

average state of the rails. Now these being the data, an inclined plane, rising one yard in a hundred, will present no impediment on the ground of adhesion, provided the system be to maintain the same speed throughout the journey; for supposing, as above, that the adhesion of the engine wheels on the level, be equal to two hundred and fifty pounds, it will be the same on the inclined, minus one-hundreth part, (two and a half pounds), a difference so small as to occur every day, in the varying states of the rails, and quite unnecessary to be taken into the calculation. The question to be decided, therefore, was, the *power* of the engine to take a load up the inclined plane, the adhesion being equal to the power, at similar speeds; for instance, seven tons on an inclined plane, rising one in a hundred, is a proportionate load to thirty tons on a level, at fifteen miles per hour, the weight of the engine being four and a half tons, as explained hereafter; but if it be attempted to take thirty tons up the plane, by going proportionately *slower*, the power of the engine might do this, but the adhesion of the wheels would be insufficient, and they would turn round, while the engine stood still; because thirty tons on the inclined plane are equal to ninety-nine on a level, and we have supposed the adhesion to be equal to forty tons on a level. It follows, therefore, either that the engine must be worked below the adhesiveness of the wheels on the level, or the proportionate load cannot be increased by diminishing the speed on the inclined plane.

During the trials at Rainhill, in October last, "The Rocket" frequently ascended the Whiston inclined plane, with a carriage holding from twenty to thirty passengers, at a speed of from fifteen to eighteen miles per hour; and the ease and regularity with which this was effected, produced a general impression, that even up inclined planes the locomotive engine would be the power employed. Indeed, the feeling at the moment was very prevalent, that it was immaterial whether the engine travelled up an inclined plane, or on a level; but subsequent experiments have fully established, what it would have been only rea-

sonable to assume, *a priori*, that the power of an engine diminishes in proportion to the degree in which the plane is inclined, till it reaches a point when, adhesion terminating, the wheels turn round without advancing, and that, therefore, without assistance of some sort, ascending such inclines as those of Whiston and Sutton, an engine must either go at a less speed, or draw a less weight. For example, "The Comet" locomotive, a new engine, on the same plan as "The Rocket," ascended the Whiston inclined plane, with about twenty-six tons behind her, with a speed diminishing from the rate of between sixteen and eighteen miles at the commencement, to about three or four miles per hour, before she reached the top. But it would be quite erroneous from these data, to take the average between three and eighteen, and to infer that the power of the engine was equal to convey a load of twenty-six tons up an inclination of one in ninety-six, at ten miles and a half per hour; her real power, estimated in a continuing speed with the above load, being only three or four miles, or proportionate to about seven tons up the same plane, at fifteen miles per hour.*

On the 14th of June, of the present year, an experiment was made, as a preliminary measure to a general opening, well calculated to exhibit the peculiar character of railway conveyance, and to put to the test the capabilities o. the locomotive engine, both on a level and up inclines On this occasion the directors, in two carriages, proceeded on a journey of inspection, from Liverpool to Manchester and back. "The Arrow," another of Mr. Stephenson's engines, was the proving power. The gross weight drawn was about thirty-three tons, consisting as follows:—

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* It is worthy of remark, in connexion with this branch of the subject, that, in considering the section for a proposed rail-way, the *length* of the inclined planes should be taken into the account, as well as the steepness of the ascent; since, on a plane half a mile long, it is evident much more may be accomplished, than on one three or four times that length.

	Tons.
Stone, in seven waggons	20
Weight of waggons	7
Engine-tender and six persons	3
Two carriages and twenty persons	3
	33

With this load, she travelled from the engine-house, Liverpool, to Old Field-lane Bridge, Salford, Manchester, the distance being about twenty-nine miles, in two hours and twenty-five minutes, including two stoppages to take in water. Up the Whiston inclined plane she was assisted by "The Dart," an engine of similar construction and power; and the first quarter of a mile of the ascent was accomplished at a speed of seventeen miles per hour, before the summit was gained, the mile and a half being accomplished in twelve minutes; the average speed being therefore seven miles and a half per hour. At the top of the ascent the "Dart" was unyoked, and the "Arrow" proceeded, with her cargo, along the straight and level plane at Rainhill, at the rate of sixteen miles an hour. On the return from Manchester, the engine-tender, and the two carriages with passengers, constituted the whole load drawn. The first nine miles and a quarter, from Old Field-lane Bridge to Glazebrook Bridge, including the Chat-moss district, were accomplished at a speed averaging from nineteen to twenty miles per hour. The whole distance was accomplished in one hour and forty-six minutes, including stoppages, the speed generally varying from eighteen to twenty-five miles and upwards per hour, and the engine not working to her full power a great portion of the way. The speed of the Sutton inclined plane (without any assistant engine) averaged more than fifteen miles per hour. The day was wet, and the rails in some places very dirty; the whole performance, therefore, took place under circumstances by no means favourable, but the result was highly satisfactory.

Perhaps the most striking result produced by the completion of this rail-way, is the sudden and marvellous

change which has been effected in our ideas of time and space. Notions which we have received from our ancestors, and verified by our own experience, are overthrown in a day, and a new standard erected, by which to form our ideas for the future; speed, despatch, distance, are still relative terms, but their meaning has been totally changed within a few months: what was quick, is now slow; what was distant, is now near; and this change in our ideas will not be limited to the environs of Liverpool and Manchester, it will pervade society at large. A transition in our accustomed rate of travelling, from eight to ten miles per hour to fifteen or twenty (not to mention higher speeds), gives a new character to the whole internal trade and commerce of the country. A saving of time, is a saving of money. For the purposes of locomotion, about half the number of carriages will suffice, for the aggregate travelling, or transit of goods, may be doubled, or more than doubled, without any additional expense to the community. The traveller will live double times; by accomplishing a prescribed distance in *five* hours, which used to require *ten*, he will have the other five at his own disposal. The man of business in Manchester will breakfast at home, proceed to Liverpool by the railway, transact his business, and return to Manchester to dine. A hard day's journey is thus converted into a morning's excursion.

It has been well observed in our public journals, that Manchester is thus brought as near to Liverpool, as the east to the west end of London; whether we estimate vicinity by the cost of conveyance, or the time not unfrequently spent in effecting it. Gradually, the whole internal traffic of the country, with all the varieties of local intercourse, will assume a new character. Already a rail way, on a grand scale, is advertised, from London to Birmingham, and from Birmingham to Liverpool; and thus is commenced that grand trunk, which will unite the north and the south, and bring into closer communication the capitals of England, Scotland, and Ireland. There can be no question that foreign countries will adopt the rail-

way communication, as one great step in mechanical improvements and commercial enterprise. France, Germany, and America, have already their rail-ways, and the Pacha of Egypt may be expected to follow close on the heels of his brother potentates. The country of pyramids, of Memphis, and of Thebes, will then be celebrated for railways and steam carriages; the land of the proud Mameluke or the wandering Arab, of sphynxes and mummies, will become the theatre of mechanical invention, science, and the arts. From west to east, and from north to south, the mechanical principle, the philosophy of the nineteenth century, will extend itself, and the whole world will receive a new impulse.

On the 15th of September, 1830, this stupendous work was opened for public use, before countless myriads of people assembled to witness the show, ceremony, procession, and festivity provided for the occasion. Eight locomotive engines, all constructed by Messrs. Stephenson and Co. of Newcastle, were put into requisition for this purpose, *viz.* the Northumbrian, the Phœnix, the North Star, the Dart, the Comet, the Arrow, the Meteor, and the Rocket, which last is the identical engine we have recently described and referred to, see page 608. Messrs. Braithwaite and Ericsson had also constructed two engines for the procession, of very beautiful appearance, but as they proved to be in an inefficient state for working, they were not employed on the occasion. The arrangements made for the procession were excellent. Each engine had a train of carriages, with distinguishing colours and ensigns, and every visitor to whom a seat was assigned, had a card of a similar colour, with a number upon it, answering to the number affixed to his seat, by which all confusion in marshalling the company who rode in the carriages was avoided, as each visitor had only to place himself under the colour and number represented on his card of admission.

The Northumbrian was appointed to take the lead in the procession, drawing a splendid carriage, appropriated for the reception of the most distinguished individuals

who attended the ceremony. The total number of persons accommodated with seats amounted to nearly seven hundred. At twenty minutes after eleven o'clock, the procession commenced its progress towards Manchester, the Northumbrian taking exclusively one of the two lines of rail, and the rest of the engines the other.

A public writer, who was present, eloquently observes, "The brilliancy of the *cortége* the novelty of the sight, considerations of the almost boundless advantages of the stupendous power about to be put in operation, gave to the spectacle an interest unparalleled. On every side the tumultuous voice of praise was heard, and countless thousands waved their hats, to cheer on the sons of enterprise in this their crowning effort. After passing Wavertree Lane, they entered the deep ravine at Olive Mount, and the eye of the passenger could scarcely find time to rest on the multitudes that lined the roads, or admire the various bridges thrown across this great monument of human labour. Shortly afterwards, Rainhill Bridge was neared, and the inclined plane of Sutton was ascended at a slackened rate. When the summit was gained, twenty-four miles an hour became the maximum of the speed. About noon, the procession passed over Sankey Viaduct. The scene at this part was particularly striking. The fields below were occupied by thousands, who cheered us as we passed over the stupendous edifice; carriages filled the narrow lanes, and vessels on the water had been detained, in order that their crews might gaze up at the gorgeous pageant passing far above their mast heads. Shortly after we passed the borough of Newton, and reached Parkside, seventeen miles from Liverpool." Here the engines stopped to take in a supply of water and fuel. The Phœnix and the North Star having taken in their supplies, had resumed their journey, and passed the Northumbrian, which remained stationary on the other line, in order that the whole train of carriages might here pass in review before the distinguished company of the Northumbrian. Several gentlemen embraced this opportunity to alight from the state-carriage, and were walking about

"The idea of employing horses to impel a carriage, by travelling and exerting their strength within it, seems to be new, and whatever merit may belong to it, is exclusively due to Mr. William F. Snowden, of Oxford-street, who has taken out a patent for the invention. The reason assigned by that mechanist for employing horses in this peculiar manner is, that they cannot exert their natural strength in any other way at present known, that is, so as to be able to draw or propel a heavy weight with an *equal degree of speed*. His argument we will state, after having described the wheel-way upon which the carriages are proposed to travel.

"At *b b*, is shewn a vertical cross section of the road, in which an excavation is made, and the ground well rammed, so as to lay down, at stated regular distances, a series of cast-iron frame pieces or sleepers, *c c*, (represented in the figure quite black). In the several partitions of these iron sleepers are placed, lengthwise of the road, four lines of timber, end to end, uniformly breaking the joints, as it is termed; or so that the joints in any one line shall not be opposite to those of another. The two principal rails, those shewn at *d d*, are of oak, and of a sufficient depth to stand about three inches above the level of the other parts, when bedded in the iron sleepers. The other two lines of timber *e e*, are three-inch deal planks, set up edgewise, and bolted to the iron framing. Resting upon these deal planks and the iron partitions, and flush with the oak timber, are laid, crosswise of the road, short pieces of three-inch oak plank, leaving an open space or crevice, about one inch and a half wide between them. These short planks are laid edge to edge, uniformly along the whole line, forming with the oak timbers a regular level floor, upon very solid bearings; and over this floor is screwed down a complete covering of wrought-iron plates *a a*, as they come prepared from the rolling mill. Thus is made a hard, smooth, and firm surface for the wheels of the carriage to roll upon.

"Inside of the trunk or hollow space, formed by the wheel-way described, a small machine, called, by the patentee, his *mechanical horse*, is caused to travel by the

motive force applied above; it consists of an iron frame work, to which are attached certain horizontal toothed wheels, revolving upon vertical axles, one of which (as occasion may require,) is put into gear with a straight horizontal rack, fixed on either side to the deal planks *e e*, and extending their whole length. These horizontal toothed wheels being actuated by a steam engine, or any other first mover, will necessarily cause "the mechanical horse," to move forward in the trunk, over a space equal in length to the circumference of the wheel at each revolution; and consequently whatever is connected thereto above the wheel-way, must go along with it. The connexion is effected by standards fixed in the mechanical horse, which pass through the opening in the wheel-way, and are attached to the middle of the carriage; the weight of the carriage is not however supported by the standards, but rests entirely upon the ordinary wheels, which thus relieves the toothed wheels and rack of an immense quantity of friction, and allows them to act freely and unimpeded by the weight above.

Only two toothed wheels are shewn in the hollow trunk of the wheel-way, there is however another, which cannot be seen in this view, which, when put into gear with the opposite rack, reverses the rotary motion, and causes the carriage to proceed in the same direction ; the manner in which this is effected by gearing of the kind, is too generally understood to need further description. The lowest wheel of the three is made light, and without teeth, being employed as an anti-friction roller, and to keep the toothed wheel uniformly in the pitch line of the rack; it therefore occupies the whole space between the two three-inch deals.

In ascending or descending a hill, the floor of the carriage is preserved in its horizontal position, that the horses may not be impeded in their work, by being placed on an inclined plane; for this purpose there are two elevating screws *s s*, which are so contrived with joints, that an attendant, operating upon one of them, raises one end, and depresses the other, as the whole body of the carriage is made to turn on the horizontal shaft *t* and *u*, resting upon

strong bearings, and the whole is braced together by a suitable frame work.

If a steam engine were to be employed as the motive force instead of horses, all that would be requisite would be to attach to the vertical shaft, which carries the horizontal toothed wheel (shewn in gear in the trunk,) a spur wheel and pinion, and to connect the crank of the engine thereto. Now, if the steam engine thus employed, be of the power of two horses, it will have to be carried along with the coach, and its weight will be added thereto. Then it is argued, if it be desirable to carry the steam engine, why not carry the same power, in the form of horses, which would be less weight than all the apparatus of the former; and passengers generally, it is presumed, would give the preference to the company of horses, as travelling companions, to that of a steam engine boiler. It is true, that, as the horses have to move in a circle, a clear space of about sixteen feet wide would be required for such a carriage to travel in, but as the road would be adapted to the carriage, that difficulty is considered to be obviated.

The patentee calculates the power of an average horse, in drawing a load at the rate of two and a half miles per hour, for four hours a day, as equal to a force of about two hundred and fifty pounds, when drawing in a straight line; if the speed of the horse be doubled, that is, five miles per hour, the force he can apply is not more than fifty pounds; and if it be increased to ten miles per hour, the horse can do no work whatever, except during a very short space of time; two miles and a half per hour is therefore considered the most advantageous pace for a horse to exert his strength, in drawing a burthen. As, however, the contracted circle of a mill-walk is unfavourable for the full exertion of a horse's powers, Mr. Snowden supposes the useful effect to be about two hundred pounds. Having got this available force, he then proposes to sacrifice three-fourths of it, in order to gain an equivalent in speed; or, in other words, ten miles an hour, in which the force applied would be but fifty pounds each horse. This will be readily understood, on reference to the lower figure in the engraving; *g g*, are two yokes, (to which the

horses are attached,) of a horizontal lever, fixed to the main shaft *h*, on which is also fixed (close to the floor of the carriage), the large horizontal toothed wheel *i*, of twelve feet in diameter; the revolution of the large wheel *i*, gives motion to the small pinion *j*, one foot in diameter; which pinion being on the same spindle as the toothed wheel, three feet in diameter, of the "mechanical horse" (shewn in gear with the rack), causes it necessarily to revolve with a speed quadruple that of the horses; or to pass over a space four times greater in the same time; or at the rate of ten miles per hour. It now remains to be seen what load can be moved at the rate of ten miles an hour, by the united force of two horses applied as before mentioned, *i. e.* one hundred pounds. It is presumed that this will amount to six or seven tons, upon a level rail-way; and upon reference to Mr. Tredgold's work on rail-roads, we find this to agree very nearly with Mr. Snowden's statement of the effects produced by this power. The weight of the horses is therefore of trifling consideration, if the advantages attending this mode of applying their strength be so great.

Having now extended our description of the various kinds of locomotive carriages, and railways, as far as the limits of this work will permit, we proceed to notice, briefly, some improvements that have been proposed in that very important part of a rail-way carriage, the axles.

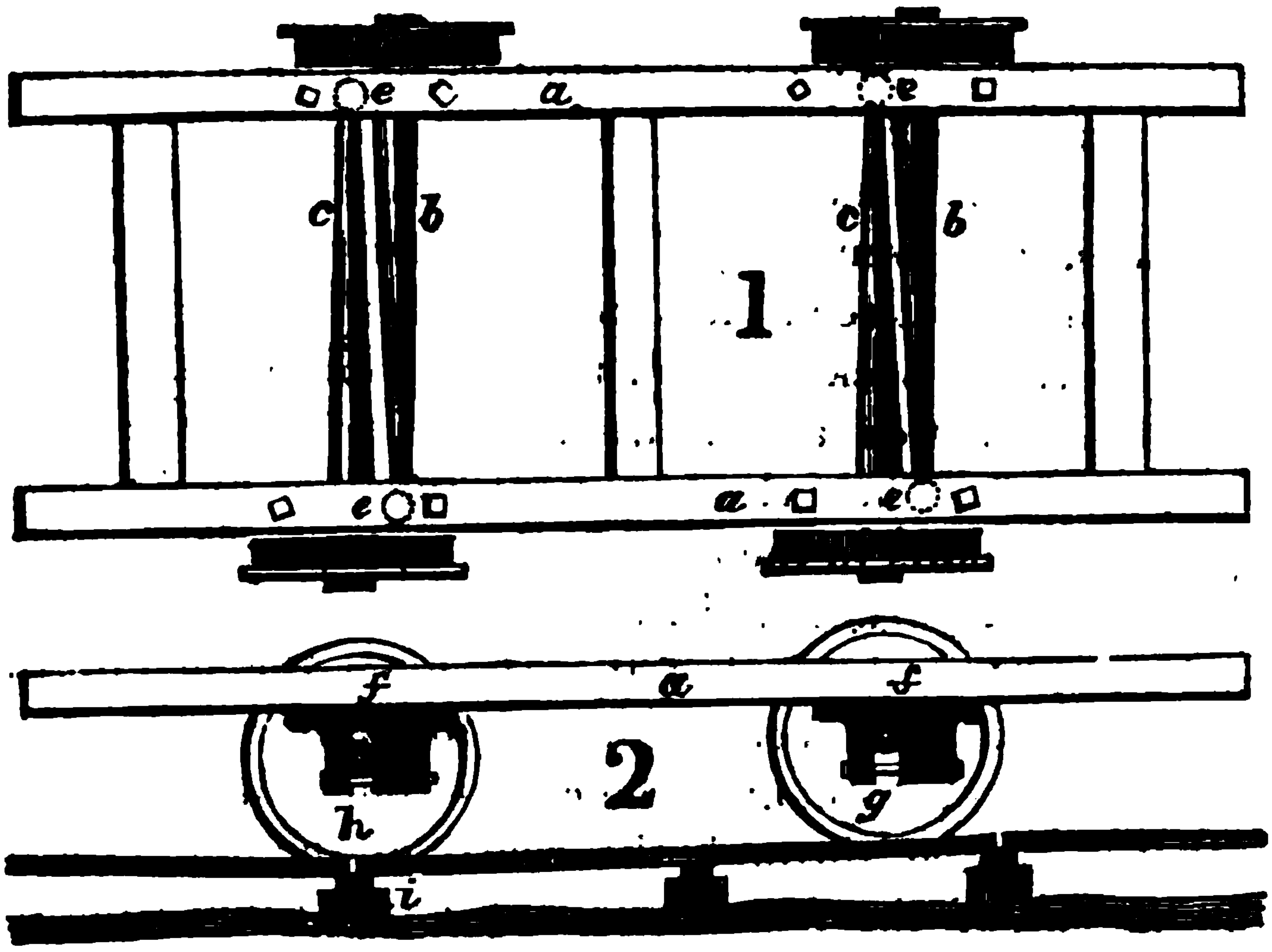
The first is an invention of Mr. Robert Stephenson, of Newcastle upon Tyne, which is intended to obviate the extra friction produced by the wheels of carriages, when they are proceeding along curved portions of the rails. Instead of two wheels, fixed as usual to the extremities of one axletree, Mr. Stephenson's plan is to have a separate axletree to each wheel, so that they may revolve independently, and at different velocities, as circumstances may require. The outer wheels of a four-wheeled carriage, (or those which are on the longest of two curved parallel lines,) will therefore be at liberty to run faster than those on the inner side, (or on the shortest line,) thereby pre-

venting that sliding motion, and its destructive effects, when passing round curves, which, on extensive lines of road, are generally found unavoidable.

Mr. Stephenson's improvements in axles likewise embrace another object of more momentous importance, that of providing a remedy for the unequal strain to which a carriage is subjected, in passing over those parts of a rail-way that lie hollow, or below the level of the contiguous parts, owing to the sleepers, or other supports, having sunk or given way, which causes the carriage and its load sometimes to rest upon three wheels instead of four, producing undue strains or fractures; and at other times causing the carriage to pass off the rails. To provide against these circumstances, the axletree of each wheel turns in a fixed bearing, which is bolted to the frame of the carriage; this bearing, instead of having a circular aperture for the axle to turn in, has a long vertical slot, in which the axle can rise up and down, as may suit the undulations or imperfections of the line of rail. This, however, could not take place, unless the opposite extremity of the axletree moved upon a universal joint, which Mr. Stephenson has adopted, giving the preference to the ball and socket for that purpose, on account of its strength and simplicity.

Patent Axletrees and Bearings, by Mr. Robert Stephenson of Newcastle-upon-Tyne. 1825.

Fig. 1, exhibits a plan of a carriage-frame, with its wheels and axletrees; and fig. 2, a side-elevation or section, as seen from the interior of the frame. Similar letters of reference in each figure indicate corresponding parts. *a a*, shows the frame of the carriage; *b c*, *b c*, the four tapered axletrees, having, at the small end of each, a globular knob, revolving in a hollow spherical socket, as seen at *e e e e*. In fig. 2, the bearings *f f*, are shown bolted to the carriage-frame *a*; at *g*, the axletree is seen in the upper part of the bearing, and at *h*, the axletree is shown to have fallen down the slot, allowing the wheel to accommodate itself to the sunken part of the rail *i*.



In this last contrivance, the wheel alone is supported, and the carriage has still to sustain the unequal pressure, owing to its resting upon three wheels. The chief advantage that results from it is, in keeping the wheel always on the rail; because, if the hollow was so great as to allow the flanch to rise above the surface of the rail, the carriage might, in its progress, be thrown over, producing very serious consequences.

An accident of this kind recently occurred to the new locomotive carriage of Messrs. Braithwaite and Ericsson, "The William the Fourth," on the Manchester and Liverpool Rail-way, by which it was very nearly thrown down a deep precipice; proving the necessity of some contrivance to effect the object aimed at by Mr. Stephenson's arrangement.

Another arrangement of parts for a rail-way waggon was recently patented in America, (by Mr. W. Howard, of Baltimore,) having for its objects the obviating the increased friction arising from passing round the curves of a rail-way, and the reduction of the friction at the axles. The following extract from the patentee's specification, explains the construction of his carriage.

"The size of the wheels, their distance apart, and the distance between the axles, are in the common proportions used in rail-way carriages. The connecting beam between the fore and hind axles, is fastened firmly thereto by jaws or frames, to prevent lateral motion. This beam is divided in the centre, between the axles, one end having a tooth, and the other a socket, cut of the epicycloid form, to keep the point of action at an equal distance from the centres of each axle. The axles are kept together by fastening the body by bolts to the beds resting upon each. Another method of construction is, to extend the beam from the hind axle, until the end of it rests upon the bed of the fore axle, while the beam from the fore axle reaches to a short distance only behind the central point of action. A bolt then passed through the centre of the hind frame, and the end of the fore frame, and equi-distant from the axles, forms the pivot or point of action between them. In this case, the waggon is fastened firmly to the hind bed only, and to the extremity of the hind beam, which rests on the fore bed, which is made to traverse, laterally, more easily by a small roller upon a curved strip of iron.

"The friction-wheels are contained between upright stands or supports, of cast or wrought iron; each wheel having one on each side, connected at the top by a bolt and nuts, and having jaws at the bottom, wide enough to admit the axle in contact with the friction-wheel; each pair of friction-wheels is connected by iron bars passing through each arm of the jaws of the supports, and secured by nuts: between these bars the axle revolves, and the bars, rising above the axle, receive the beam, and form the fore and hind bends, to which the frames of the beam are securely nutted. To obviate the little friction which may arise from the centre of the friction-wheel being directly above the centre of the axle, it may be placed a little obliquely, and a small friction-roller used in one of the arms of the jaws, to destroy the additional friction there.

"The axles have two shoulders at each end, one of which supports the waggon wheel, and is either firmly

fixed to it, or only secured by a linch-pin, and the other revolves upon the friction-wheel.

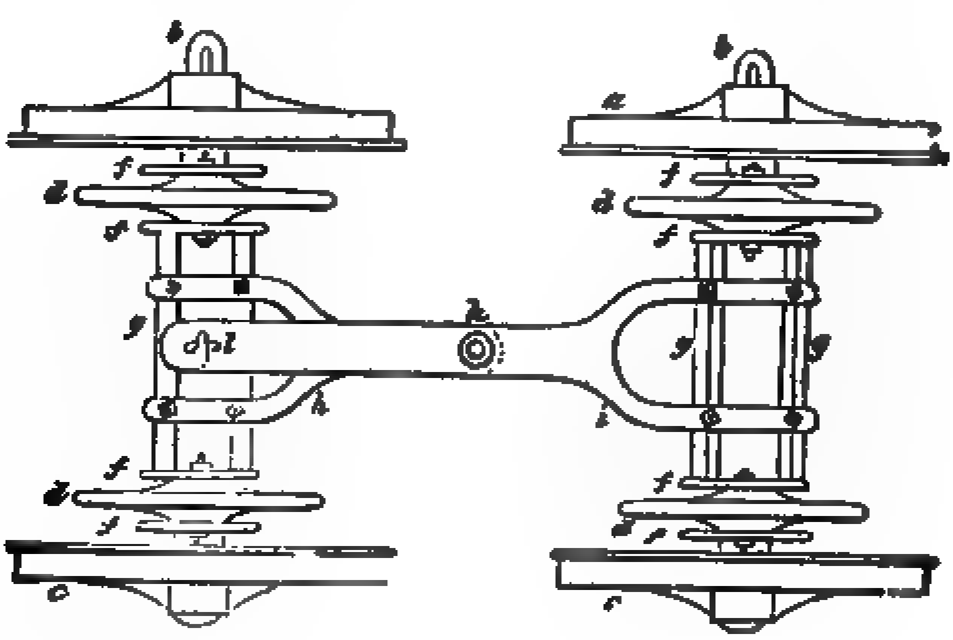
" These principles are not new, but the combination of them into a rail-way carriage is new, and entitles, the inventor believes, that his invention be secured by patent. The peculiar application of friction-wheels is also new, and claimed as original."

Fig. 1, represents a perspective view of the whole carriage, with its friction-wheels attached.

(FIG. 1.)

Fig. 2, represents the plan of the waggon, showing particularly the manner in which the beds of the two axles are connected.

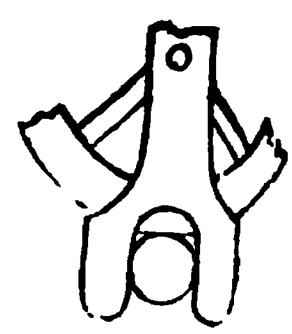
(FIG. 2.)



a is the iron waggon wheel, made as usual, except that it is arranged so as to turn on the axle, to which it is secured by the linch-pin *b*, or any other contrivance. *c* is a wheel fixed upon the axle, as in the common rail-road carriage. *d d*, the friction-wheels, moving upon the axles *e e*, and supported by the supports *f f*. The whole of these parts are of wrought or cast iron, and the frames are secured together by screws and nuts, so as to keep them solid, and as shown in the figure *g*, one of the bars connecting the two frames together, and secured in like manner. *h* and *i*, are the two frames by which the two beds are connected by a bolt, at the point *k*, equi-distant from the centre of each axletree, the frame *i* of the hind bed is prolonged, and rests on part of the frame *h*, immediately over the fore axle, the motion of its end, laterally, being facilitated by a small roller at *l*.

Fig. 3, represents the shape of the frames *f f*, permitting the axle to rest on the periphery of the friction-wheels. In the arrangement here drawn, it is proposed to fix, firmly, the body of the waggon on the hind bed and frame *l*, to move with it. Another method is, to attach each bed to the body by a bolt at *m* and *n*, round which the beds must be made to traverse. The frames are then to be connected at *o*, one having a tooth and the other a socket. These are to be cut of the epicycloid form, which will keep the point of action at an equal distance from each of the centres *m* and *n*.

(FIG. 3.)



If it be found objectionable to place the body of the waggon entirely above the wheels, the two friction-wheels on one bed may be placed on a common axle. This arrangement will simplify the number of parts, and contribute to the steadiness of the motion.

SECTION VI.

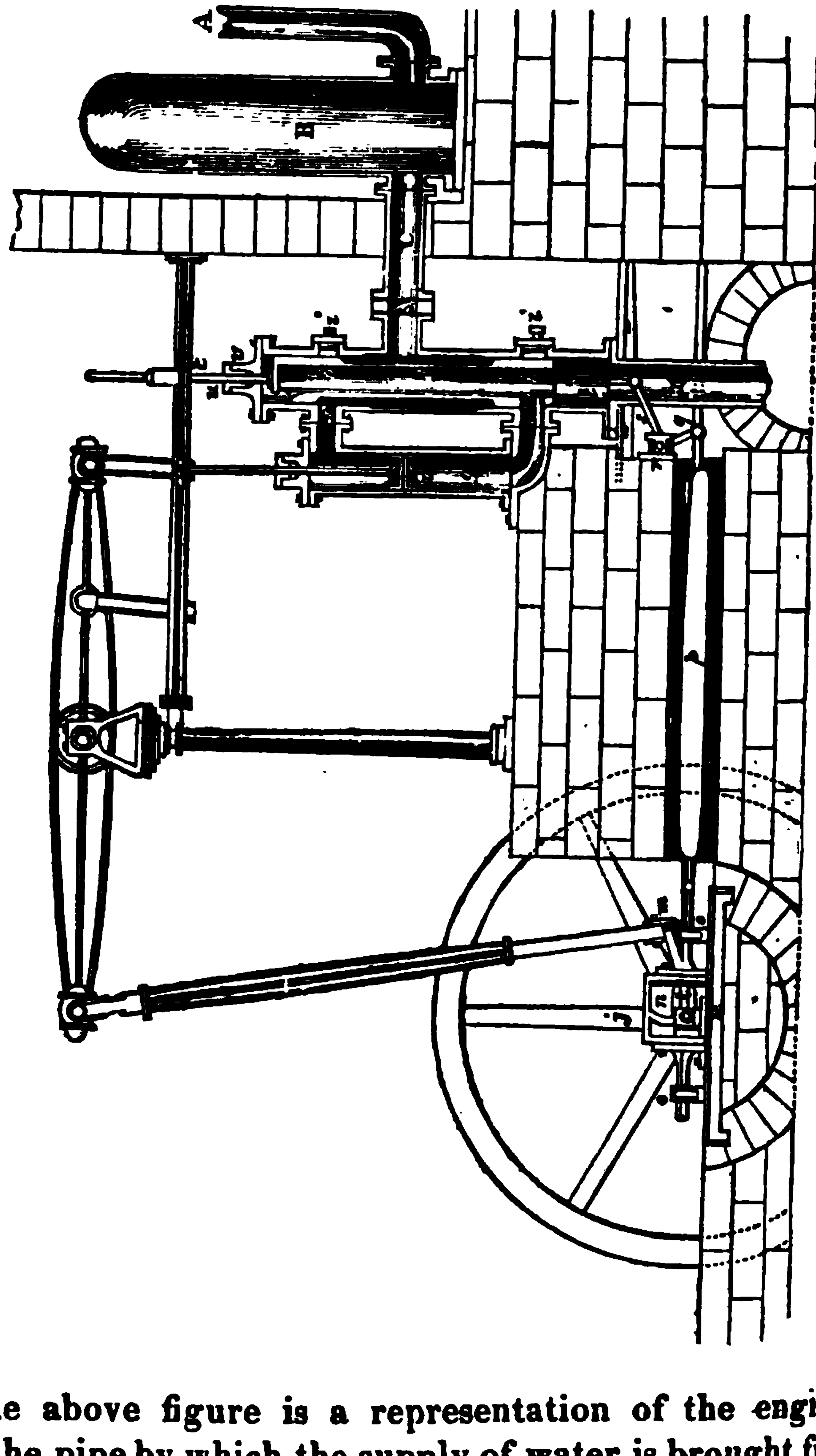
MOTIVE ENGINES.

UNDER this title is comprehended a description of a variety of engines, in which the pressure of water, and the elastic force of the vapours, as well as the gases, of various bodies, are employed as motive power, in lieu of steam.

It is well known that the expansive force of fluids, generally, is augmented by an increase of temperature, and that most of them are so affected in a greater ratio than water, by a similar accession of heat. This fact has led many ingenious men to devise machines for the application of their forces; and although but little success has hitherto crowned their labours, (with the exception of water engines,) there are fair grounds for hope that eventually a useful power, in peculiar situations, may be derived from some of them. In the first part of this work the gas-vacuum engine of Brown, and the carbonic-acid-gas engine of Brunel have been described; those which follow are equally deserving of notice, and will at least furnish useful information to those who are studying the subject, or are practically engaged in endeavouring to accomplish the same object.

Statical Hydraulic Engine, erected by Mr. Manwaring, at Messrs. Cook and Co.'s Alum Works, near Whitby.

The mechanism of this engine is, in its principal features, similar to the steam engine. Instead of the elastic pressure of the *vapour* of water, the *water* itself is made to operate, alternately, upon both sides of a piston in a cylinder, with a force according to the height from which the water descends. The annexed account of the hydraulic engine at Messrs. Cook and Co.'s alum works, was drawn up by the engineer who erected it, for publication in the Transactions of the Society of Arts.



The above figure is a representation of the engine; A is the pipe by which the supply of water is brought from a head, 170 feet above the engine; B is a vessel containing air, the continual elastic pressure of which prevents the blow that would otherwise be occasioned by the descent of the water; *c* is a throttle valve; *d d* is a hollow open cylinder, working within an exterior one, and closely applied to that cylinder at the parts *e e*, *e e*, but elsewhere

leaving a vacant space between the two cylinders for the reception of the water; *h h* are packings, in order to prevent the escape of the water between the two cylinders; and *i i* are adjusting screws, to tighten the packing, in proportion as it is worn away; *f f* are two passages that lead into the upper and lower ends of the pipe *g*, in which the piston *w*, works.

When the cylinder *d d*, is in the position represented in the plate, the communication is open, by means of the upper pipe *f*, for the water to flow into the pipe *g*, *above* the piston *w*; at the same time the passage is open for the water in the cylinder *g*, *below* the piston, to flow out through the lower pipe *f*, and through the lower part of the open cylinder *d*, into the pipe *x*, which is somewhat more than 30 feet long, and terminates in a cistern of water. There is, therefore, above the cistern *w*, a hydrostatic pressure, equal to 170 feet of water, and below it a partial vacuum; the piston consequently descends to the bottom of the pipe *g*. By the time that it has arrived in this position, the cylinder *d*, will also have descended so far, as to have opened the communication between the entering water, and the lower pipe *f*, and to have shut off its communication with the upper pipe *f*; the hydrostatic pressure is therefore transferred to the under part of the piston, which consequently rises, while the water above the piston pours into the top of the cylinder *d*, and escapes through the pipe *x*.

The alternate motion of the slide or cylinder *d*, is thus effected. The rod of the piston *w*, is attached at its top to one end of the beam; at the other end of the beam is a rod, terminating below in the crank *m*; the oscillating motion of this crank is transferred, by means of the connecting bar *l*, to the axis *k*, on which is placed the curved tooth, or cam *n*; the latter is inclosed within the rectangular frame (or cam box) *j*, and being moveable in a horizontal position, is consequently made to perform a backward and forward motion, by the cam pressing first on one, and then on the other side of the box. To the outside of the box are fixed two guide bars, supported on the

bearings *o o*, the connecting rod *p*, at one end to the guide bar, and at the other end to the arm *q*, of a bent lever, having for its fulcrum the pivot *r*; the other end of the lever is forked, and embraces the pipe *x*; one of these forks *s*, is connected with a similar rod; these rods are fastened at top to the two ends of a cross bar, to the middle of which is fixed the rod *u*, which works in the stuffing box *v*, and gives motion to the slide *d*.

The slide remains stationary nearly half a stroke of the piston, in order to allow the water to act with its full force, and this is effected by its being necessary for the cam, after it has moved the box in one direction, to perform about a quarter of a revolution, before it can act on the opposite side of the box. The reason for making the passages *f f*, as large as represented, is to diminish, as much as possible, the friction of the water, which otherwise would retard the motion of the piston.

Patent Vapour Engine, by Mr. Thomas Howard, of New Broad Street, London. 1826.

The intention of the inventor of this engine, was the employment of alcohol or ether, as a motive power, on the ground of their exerting a much greater expansive force than steam, at similar temperatures. As the expense of alcohol and ether is too great to allow of any considerable waste of the kind, one of the principal difficulties attending the construction of an engine of the kind, has been to prevent the escape of the vapour. In this machine the vapour is generated in the cylinder itself; therefore, no distinct boiler being employed, the apparatus is very compact and light. The following description we gather from the specification of the invention.

"I erect two metal cylinders, (*a b*, figure No. 1), made firm and secure by any of the ordinary methods. These cylinders communicate with each other, at the lower part, by a horizontal tube, or smaller cylinder, or otherwise, so as to form a free passage at *c*, from one to the other. Then such a quantity of fixed oil, mercury, or other fluid, or substance becoming fluid, but not evaporating at the degree of

heat to which it will be there exposed, is introduced into these cylinders, as will fill the base of the one, the intermediate passage, and nearly the whole of the other cylinder, to serve as a medium of heat necessary for generating the vapour for working the engine. Within one cylinder *b*, is placed a piston, exposed above to the pressure of the atmosphere, and having a rod and stuffing in the usual manner. In the other cylinder *a*, is placed a thin metallic dish *d*, floating freely upon the oil, or other fluid before-mentioned. This latter cylinder has a top fastened down, quite air-tight, through the centre of which top is brought a tube *e*, proceeding from the condenser (hereinafter described), the lower end of which tube within the cylinder terminates in a nosle pierced with many small holes. This tube is passed through a piece of cork, wood, or other imperfect conductor of heat, fixed into the top of the cylinder with a ring screwed down above it, in which the tube is made secure by a small screw *f*, in order that all these parts may be air-tight. In the top of the cylinder *a*, is an oblong orifice, closed by a valve *g*, of the like form, which opens inwards by a rod *h*, striking the valve near one end, with the advantage of a lever (as a door), at which end is a small hollow, for the purpose of receiving the rod; at the other end, the valve is confined to its seat by a crane-neck spring, bending over above it, (as in the figure No. 1. near *g*); the rod is entirely detached from the valve, so that the rod has the power only to open the valve. The advantage of which is, that any accidental irregularity in the motion of the rod will not derange the valve itself. The valve rod passes through an air-tight stuffing box *i*, in the usual manner. A safety valve *k*, is placed on the top of the cylinder *a*. There is an orifice, *l*, through the piston, into which is fitted a plug or stopper *m*, by means of which the height of the oil, or other fluid hereinbefore described, above the piston (which should always be kept a little above the piston), may be regulated when necessary. The oil, or other fluid, may at any time, when required, be withdrawn from the cylinders by a cock, *n*, near the bottom, and may be again in-

troduced by the top of the piston cylinder, through the orifice *l*, in the piston. The degree of heat necessary for the purpose of working my vapour engine, is obtained by means of a sufficient number of lamps, *o*, *o*, *o*, *o*, on the principle of the argand lamp, and on a larger scale when required. These lamps are supplied with oil, or other inflammable liquid, or gas, and placed below the cylinders, and the chimneys of which lamps are passed into, and through a thin metallic or other covering, which covering is carried round both the cylinders, (except the upper part of the piston cylinder), at a small distance from the cylinders, so as to confine and carry the heated air entirely round them. The lamp chimneys should be made of metal, with a hole therein, covered with talc, through which the flame may be seen for the purpose of regulation. There is a tube or chimney, *p*, at the top of the last-mentioned covering, which tube may be more or less closed by a top or register, *q*, the better to regulate the heat of the air within the covering. By means of a small forcing pump, *r*, which is set in motion, and the length of its stroke regulated by any of the ordinary methods in use in the steam engine, the tube *e*, which enters the top of the vapour cylinder, is supplied from the condenser with the liquid, which is afterwards to be converted into vapour, within the cylinder *a*. The liquid to be employed may be either ether, alcohol, essential oil, or other liquid, which evaporates more rapidly, and at a lower temperature than water. I do not however confine myself to any particular liquid or liquids, for even water may be used, if the heat be sufficiently raised. The degree of heat to which it is proper to raise the oil, or other fluid medium within the cylinders, must be varied according to the nature of the liquid to be evaporated, and to the extent of power required. In order readily to ascertain, and be enabled to regulate correctly, the degree of heat within the cylinder, a thermometer is attached to any convenient part, with its bulb passed through the cylinder into the oil or other fluid medium. From the nosle of the tube *e* above described, a sufficient quantity of the liquid before mentioned

is thrown by the action of the forcing pump *r*, not gradually, but quickly, and at once upon the dish D, which being previously heated by the oil, (or other fluid medium) on which it floats, quickly converts the liquid thrown on it into vapour, which vapour receives an increase of expansive power, by the heat of the cylinder; and pressing upon the oil (or other fluid medium) and dish floating thereon, forces the oil through the horizontal passage C, into the piston cylinder, and raises the piston to its highest point of elevation. The valve G in the vapour cylinder, being now opened, the vapour escapes by a tube S into a separate vessel (as in the steam engine of Watt) and is there condensed; the piston then returns by the pressure of the atmosphere, and the dish is carried again to the top of the vapour cylinder. The valve G is now closed, and a fresh portion of liquid is thrown by the forcing pump upon the dish, to be converted into vapour, and the operation is repeated as before. The dish D is not absolutely necessary, as the liquid may be thrown upon the oil (or other fluid medium); but I prefer a dish, which should be made of copper, with a flat bottom, the internal surface of which should not be polished. A sliding valve T, is placed across the horizontal tube or passage between the two cylinders, so as occasionally, either entirely or partially, to close the passage from one cylinder to the other, by means of which the motion of the engine may be easily regulated or stopped. In the top of the cylinder A, is fixed a tube S, by which the vapour is conveyed from the cylinder to be condensed; and the tube should be divided, and a ring of cork, wood, or other imperfect conductor of heat *a*, should be placed between the two parts, which should then be screwed up together air-tight. By means of this arrangement, the transmission of the heat from the cylinder to the condenser is interrupted. The other end of the tube is inserted into, or communicates with, a circular tube or hollow ring, VV, into which a number of smaller tubes, marked severally U, made of copper or other metal, as thin as the required strength will permit, are fixed and arranged in a circle. These smaller tubes are also inserted into ano-

ther vessel below W, which forms a reservoir for the vapour, when condensed. The liquid formed by the condensed vapour may, by means of a pipe, with a cock *d*, placed in the bottom of the vessel, be withdrawn when required. The outer and upper part of the condenser has upon it a circular bason or open vessel X, into which water is thrown by a pump or otherwise, as may be convenient. The smaller tubes severally marked U, are each wrapped round, and covered on their external surface with flannel, or other porous substance of the like nature, which is carried over into the upper ring or bason X, from whence, being previously wetted, the water is absorbed, and the flannel, or other porous substance used, acting like a syphon, conducts it down the outside of these tubes into a vessel Y below them, from which it may be allowed to run off, or be pumped again into the upper vessel X, if required. Within the hollow circle formed by these smaller tubes, severally marked U, is a machine upon the principle of a fan, kept in rapid motion by the engine or otherwise. By this means, a continued stream of air is thrown upon the wet flannel, or other porous substance, and the heat is consequently thereby more quickly withdrawn from the condenser. Previously to setting the engine to work, it is necessary to withdraw the air from the condenser and vapour cylinder, which is done by means of an exhausting pump or syringe applied at *c*, to a pipe with a stop-cock *b*, fixed on the top of the condenser. The liquid to be converted into vapour for working the engine, is introduced into the vessel or reservoir at the bottom of the condenser, through a tube *e*, closed by a screw cap *f*. From this vessel or reservoir, (the fluid in the cylinder having been first heated,) the liquid is thrown into the cylinder A, by the forcing pump R, as before described. A mercurial guage may be fixed in the usual manner to any part of the condenser, in order to shew the degree of exhaustion within. This method of producing condensation, consists in exposing the vapour, or elastic fluid to be condensed, to a large surface of metal surrounded or covered with flannel, or some other porous substance, continually absorbing water,

and at the same time acted on by a stream of atmospheric air, and I claim the application of this new method of producing the condensation of the elastic fluids or vapour as applicable generally, and not as applicable to my engine only. The condensation of the vapour or elastic fluid may also be effected by injection, upon the same principle as in the steam engine, but with the advantage of dispensing with the constant use of an air-pump, and effectually preventing the escape of any of the vapour or liquid. To effect the condensation by injection, a tube S, (figure No. 2) conveys the vapour into an oblong vessel *g*, made of copper or other metal, as thin as the pressure will allow. The required quantity of the liquid before mentioned, to be afterwards thrown into the cylinder, is introduced into the condenser or vessel *g*, by the tube *e* as before, or by a funnel *o*, on the top through a stop cock *p*. The forcing pump R, the E to convey the liquid into the cylinder, the pipe and cock *b* for withdrawing the air, and also the pipe and cock *d*, by which the liquid may at any time be withdrawn, are constructed as in the hereinbefore described, and the lifting pump withdrawing a quantity of the liquid, is dispersed throughout the vessel *g*, and, condensing the vapour therein, passes with it to the bottom of the vessel. Part of this liquid is again thrown into the cylinder by the forcing pump R, to be converted into vapour as before described, and part of it is again employed to condense the vapour, in the manner last before mentioned. In effecting the condensation by injection, t. condenser and tubes connected therewith are immersed in a cistern of cold water, a stream of which is continually passing through it, as in the steam engine. The vapour engine hereinbefore described, operates against the pressure of the atmosphere." (This may be avoided, and a double action produced, by arrangements similar to those in steam engines, which are described by the patentee.)

"Although I prefer the use of lamps upon Argand's principle, in order to obtain the requisite degree of heat, to give motion to my vapour engine; yet an engine may be so constructed, that fuel of any kind may be used. The foregoing are some of the combinations of machinery, to

which my invention is applicable; but I moreover claim, as my exclusive invention, the application for the purpose of giving motion to machinery, of vapour generated from such liquids as evaporate at a lower temperature than water."

The annexed diagram is explanatory of another form of engine, suggested by Mr. Howard, which operates against the pressure of the atmosphere, and upon which also depends the return or vacuum stroke of the piston. Two methods of avoiding this, and producing a double action, are given in the specification, but which are not inserted here. The following diagram presents an outline of a very effectual arrangement. *a a* are the vapour cylinders or vessels, (the form of which may be varied;) *b* is the piston cylinder; c, the piston, working horizontally. The arrangement of the lamps, injecting tubes, &c. is upon the same principle as before. The vapour is alternately generated within, and withdrawn from the two vessels, *a a*, and acts upon the piston through the medium of the oil or other fluid, upon which, or upon the thin copper floats *d d*, the small quantity of liquid to be evaporated is injected, as before described.

In the Register of Arts, (vol. 4, page 66, from whence this account is extracted,) are contained some additional observations on this subject, by the ingenious patentee, which appearing to us to be well deserving of the consideration of the reader, we here transcribe them.

"The leading principles upon which this invention is founded are, the generating no more vapour than is actually demanded to produce the required effect; the further expansion of the vapour in the vessel in which it operates; and the employment, under these arrangements, of such liquids (though not exclusively) as evaporate more rapidly, and at a lower temperature, than water. It is obvious that the first principle cannot be effected, when there is employed a boiler, or generator of any kind, dis-

tinct from the cylinder or other vessel in which the vapour operates by its pressure, and between which the communication is shut off at intervals. The advantage of preventing the cooling of the cylinder of the steam-engine was observed by Watt, and has been attempted in a variety of ways, and was successfully effected by placing it within the boiler, as in the high-pressure engine of Trevithick. But I have nowhere heard of its having been proposed to raise the temperature of the cylinder *higher* than that of the boiler. This principle could not, indeed, be accomplished with its full advantage in the steam-engine, because the expansion of the vapour by heating the cylinder would only be partial; for when the communication is open with the boiler, there cannot exist a greater pressure within the one vessel than the other; therefore, the vapour in the boiler must also be expanded, before the whole effect can be produced. When the vapour is generated, as in my engine, within the vessel in which it operates by its pressure, the same source of heat employed for the former purpose, is also made to increase the effect of the latter; the whole vessel being surrounded with a medium (ether, air, or a fluid) heated by the fuel employed to generate the vapour. By these arrangements, combined also with a fluid medium within the vapour vessel, and which likewise prevents any escape of the vapour, the loss of heat by radiation, &c. is as much prevented as perhaps it can possibly be, owing to the small extent of surface to which it is necessary to apply the fuel, and to its being made to bear at once upon the vessel in which the effect operates. When we reflect that every additional 40° of heat doubles the previously existing expansive power of the vapour, the advantages of this system will be evident. While the temperature, 40°, proceeds in an arithmetical, the expansion proceeds in a geometrical ratio, or nearly so. Other advantages are also obtained by generating the vapour in the vessel in which it operates. No injurious condensation of the vapour takes place by the injection of the liquid to be evaporated, because, at the moment of injection, there is no vapour in

the vessel; neither is there any pressure to overcome, in introducing the liquid.

"When the idea first occurred to me of employing, instead of water, liquids which evaporate at a lower temperature, I perceived immediately, that it would be hopeless to attempt the practice of such a theory upon the present principle of the steam engine; and when I afterwards found that such had actually been attempted with alcohol, I was not surprised that it had proved abortive. To say nothing of the danger of placing a furnace under a boiler containing a large quantity of an inflammable liquid, it would be almost impossible to prevent its escape, which would soon amount to far more than the saving of fuel that would be made upon *that plan*. After making many experiments, it appeared to me that the vapour might, by a new and proper arrangement, be generated within the cylinder itself, and thus do away with the necessity of a separate boiler, or generator of any kind. I ascertained that ether or alcohol would evaporate with sufficient rapidity, and would produce an instantaneous and very great pressure in a closed vessel, if the surface upon which a small quantity was thrown, were heated to about 100° above the boiling point of the liquid. In these experiments, mercury was employed as a medium upon which to evaporate the liquid. The following Table will explain the system.

Ether, at the temperature of	Alcohol, at the temperature of	Water, at the temperature of	Force of vapour in atmospheres.	Cubic inches of vapour of atmospheric pressure, produced from one cubic inch of liquid.*	
100°	175°	212°	1	1800	Pressure in vacuo at the temperature of 60° in inches of mercury:—ether 12 inches, alcohol 2 inches, water ½ inch;—
140	215	252	2	3600	
180	255	292	4	7200	
220	295	332	8	14400	
260	335	372	16	28800	
300	375	412	32	57600	

* In a subsequent communication to the scientific journal quoted, Mr. Howard observes, that the fifth column of this table must be considered erroneous.

—and so on in proportion, for every additional 40° of heat, but gradually decreasing in effect, as the temperature advances. The calculations are given only as an approximation sufficiently correct to illustrate the theory.

"Suppose it be required to work an engine with ether, having a cylinder or vapour vessel or vessels, twenty inches in diameter, and thirty inches in length, and with a pressure on the piston, or (which is the same in effect,) upon the intermediate fluid, of eight atmospheres, and which would be a very powerful engine. Such a vessel as that above described will contain about ten thousand cubic inches. This will require the evaporation of about five and a half, say six cubic inches of ether, at two hundred and twenty degrees, as six cubic inches contain nearly sixteen hundred grains or drops of liquid, five drops must be evaporated from each square inch, since the diameter of the vessel, twenty inches, presents a surface of about three hundred and twenty square inches. Five drops of ether upon a square inch of surface, heated to two hundred and twenty degrees, will evaporate with a rapidity sufficient to produce a motion equal at least to the condensing steam engine. By decreasing the heat, or the quantity of liquid injected, the effect will be decreased in proportion, so that the motion and power of the engine may be governed with great exactness. If the quantity of liquid injected be decreased, and not the heat, the power (pressure) only will be decreased: the motion, so far as depends upon the quickness of evaporation, may even be increased. The relative proportion between the motion and power also depends upon that between the surface of the piston and the surface of the intermediate fluid, which receives the pressure of the vapour. It is not necessary at present to enter fully into this part of the subject; there must be, of course, a certain modification with regard to the temperature and the quantity of liquid injected, which will be found, by practice, to produce the most advantageous result, according to the purpose for which the engine is designed, and other circumstances.

"Alcohol will furnish the same results as ether, if the

temperature be raised seventy-five degrees higher, and upon the whole, this liquid may perhaps be preferable, particularly as it may be more readily and effectually condensed.

"Water will also give the same expansive power, at one hundred and twelve degrees higher than ether, or thirty-seven degrees higher than alcohol; but the motion of the engine would be comparatively slow at this degree of heat, and, therefore, independently of the necessary increase of temperature, the greater quantity of latent caloric absorbed by its vapour, and other circumstances, the same effect can only be produced from this liquid, by a greater consumption of fuel. Nevertheless, there may be instances in which water would be employed, as, even in this case, the consumption of fuel will be very small, compared with the steam engine. It must be remembered that it is not necessary that the *whole* of the liquid injected should evaporate instantly. It is sufficient if it evaporate during the time occupied by the descent of the surface on which the pressure operates, and which pressure commences immediately upon the injection of the liquid, because a very small quantity of vapour is sufficient to fill the contracted space existing at this moment in the vessel, and which space enlarges with the increased quantity and pressure of the vapour, until the required motion be produced; when, the vapour being withdrawn, the medium within the vessel returns by the pressure in the contrary direction, and again occupies the space from which it was ejected by the vapour. It is thus that no more vapour is generated than is actually employed; and as this is the utmost degree of simplicity at which we can arrive, may we not presume, even from this cause alone, that it is the most effectual method of availing ourselves of the vapour of liquids?

"The arrangement of the argand lamps, and the manner in which the heat produced by them is made effectual, will be understood by inspecting the drawings annexed to the specification. The principle of the invention is, the permitting no air to approach the vapour vessels or

cylinders, but such as has been intensely heated by passing through the flame of the lamps. Charcoal may be employed in much the same way; but when fuel of this kind is made use of, I purpose to surround the cylinders with a fluid medium, instead of heated air, and which may also be added when lamps are used, but in this case it does not appear to be necessary. The surface exposed to the atmosphere may be coated, externally, with some imperfect conductor of heat. Many advantages will result from the employment of argand lamps, particularly in navigation. In powerful engines, they will, of course, be constructed on a large scale.

"Having completed these arrangements, it became necessary to devise some other mode of condensing the vapour than that practised in the steam engine; for the injection of fresh portions of cold water is, of course, inadmissible, when the vapour of other liquids is to be condensed. By the first method, given in the specification, the condensation is effected without injection. By surrounding the thin copper tubes with a porous substance, absorbing water from a vessel above, a continually renewed stream of it is brought into contact with them; and by subjecting this extended surface to the constant action of fresh portions of atmospheric air (which may be done in several ways), the evaporation, or, more properly, the solution in air, of the water, reduces the temperature very rapidly, about ten degrees lower than can be effected with the water only, and a small supply of water is sufficient; for I imagine that, in most cases, the water will run off sufficiently cool to be again made use of. I propose the introduction, with some suitable modifications, of this method of condensation into distilleries. The first cost will be far less than that of the heavy worm and tub at present in use, and, I doubt not, will be found more effectual.

"A method of condensation by injection is also given in the specification, and I think it preferable to the former, where a large supply of cold water is readily obtained, as in navigation. The principle is the circulation

through the condenser of the same liquid, which, after having performed its office within the condenser, is withdrawn, and, previously to being again injected, is cooled by passing through a pipe, or worm, exposed, as is the whole of the condenser, to a stream of cold water. As no air is introduced, it obviates, in my engine, the necessity of an air-pump in constant action. This method is also equally applicable to the steam engine, and would relieve it from a great part of the burthen of the air-pump.

"With respect to the safety of my invention, it will be seen, that it may be made, at pleasure, either a high or low-pressure engine. As it is very easy to construct the vapour vessels of uniform strength throughout, and as the effect of the safety-valve may be depended upon, because the vessels cannot be injured by the heat to which they are exposed, owing to the manner in which it is applied, it may be very safely proposed to extend the pressure to eight or ten atmospheres; not that this is by any means necessary to the success of the system, for a low-pressure will answer to the theory equally well; and as the size of the cylinders cannot generally be an object of much consequence, it may, perhaps, be considered preferable.

"In accomplishing this undertaking, that some of those difficulties may present themselves, which are always attendant upon the introduction of a new system, I am fully prepared to expect; but that they can only be of minor importance, I have fortunately been enabled to place beyond a doubt, by the experiments which I have made upon an engine (not yet completed) having cylinders of eight inches diameter. As it operates against the pressure of the atmosphere, this alone, were there no other indication, is sufficient proof of the power of the vapour, and which seems capable of being carried to almost any extent. The motion commences *immediately* upon the injection of the liquid. It derives its heat from four gas lamps, of the ordinary size, which appear to be quite sufficient, notwithstanding the imperfection of the arrangements. I have generally made use of ether. It stands in an area of

three feet by two feet, which is the space that would be occupied by an engine of about ten-horse power.

"It is scarcely necessary for me to point out to those who are conversant with these subjects, the advantages which will result from the employment of the vapour engine, particularly in navigation. It is proper, however, that I should take some notice of them. The most apparent are—the very small consumption of fuel; the absence of all nuisance from smoke, and of a chimney flue, when lamps are made use of; the trifling space occupied by the quantity of oil, or other material necessary, even for the longest voyage, compared with that at present required in steam vessels for the stowage of coal; the small space occupied by an engine of the greatest power; its perfect safety, portability, and moderate expense of construction."

It is now four years since Mr. Howard commenced this undertaking, during which time he has persevered with increasing confidence as to its ultimate success. We have seen an engine recently made by him, which may be deemed his second experimental engine; it is worked by the vapour of alcohol, and is formed on the plan of a boat engine, with two short cylinders and pistons, calculated to give out twenty-four horse power. We have seen it in operation, and it performs very regularly, making about thirty-three strokes per minute; the effective force had not then been determined.

Bituminous Vapour Engine, by M. de Montgery. 1826.

It appears, by the Annales de Chimie, wherein this invention was first mentioned, that it had been actually constructed, and answered the purpose. Of the last-mentioned fact, strong doubts may however be entertained, since nothing has been heard of it for the last three years. The following account includes all the information afforded by that journal, which will nevertheless furnish succeeding experimentalists with an outline of the plan adopted by M. de Montgery.

"This engine derives its power from the vapour of purified bitumen, which having operated upon the piston, is conducted to the furnace, and used as a combustible for the production of fresh vapour. The furnace and the principal part of the machinery are contained within the generating apparatus, which has a double case. In consequence of this arrangement, it is added, that vapour of a high degree of elasticity is obtained, free from danger, and the bulk of the whole machine is only a fiftieth part of a steam engine of equal power."

Gas-Power Engine, by Mr. B. Cheverton, of Ringdown, near Bristol. 1826.

"It has long been a desideratum in practical mechanics, (Mr. Cheverton observes), to possess a power engine which shall be ready for use at any time, capable of being put in motion without any extra consumption of means, and without a loss of time in its preparation. These qualities would make it applicable in cases where but a small power is wanted, and only occasionally required. They are so numerous, and the consequent saving of human strength would be so great, that the advantages accruing to society would be immense, if even the current expense were much greater than that of steam. Such an engine should also be actuated by a force so concentrated, and so compendiously appropriated, as to occupy but little space, and be but of little weight, by which it would become applicable to locomotive purposes. If, in addition to this, the consumption of materials was moderate, we should then be in possession of a mechanical agent, which would enable us to navigate the *ocean* independently of the wind, but which it is in vain to expect from our present means. It is well known that the common steam engine satisfies none of these conditions. It is true that, on the high-pressure principle, the important requisite of great power in a little compass is obtained, but it is not less true that the saving of fuel is comparatively trifling I have, indeed, been long of opinion that little of this

effect can be attributed to the greater elasticity of the steam, and that it arises chiefly from accessory circumstances.

"I was, a few years ago, led by these views to turn my attention to the gases, having been forcibly struck with the prodigious pressure under which they are capable of being generated. Gunpowder, the fulminating powders generally, but especially that remarkable fluid, azotane, are examples in point. For mechanical purposes, a gradual production of gas is of course to be adopted. The evolution of carbonic acid gas, by the action of sulphuric acid on the carbonates, was an obvious case. On making the necessary calculations, this, with many other means, were found too expensive, because the scheme embraced this principle—an expenditure of the gas. It became necessary, therefore, to take into consideration those substances which, after assuming the gaseous form, could be fixed again in the fluid state, such as alcohol, ether, turpentine, &c. These, besides boiling at a low temperature, have little specific caloric, and their vapours little latent heat. Dr. Cartwright's much-neglected engine was recollected, but the waste of costly articles was not, perhaps, sufficiently guarded against. The idea of a liquid body, as oil, intervening between the piston and the vapour, naturally suggested itself. This, however, is not altogether new, for it was acted upon in the old atmospheric steam engines; but the circumstances of the case require a modification of the plan, since the object is not so much to cut off the communication between it and the external air. For this purpose, the whole cylinder must be filled with oil.

"I have no doubt that a good engine may be constructed on this plan, but it did not fully meet my views; it was, therefore, with no little pleasure, that I read the paper laid before the Royal Society, containing an account of the experiments made by Sir Humphrey Davy and Mr. Faraday, in which the condensation of several of the gases into liquids was effected, at a temperature and under a pressure within practical limits, proving thereby that some of those gases to which my attention had been

directed on the principle of their *expenditure*, could be re-produced in the fluid form, and used again in the same way as alcohol and ether. It immediately occurred to me, as a *sine qua non* condition of an engine working with *such* materials, that there be no moving joint to which the gas can have access; in short, there must not be a possibility of its escape, and that the simplest and most obvious means of satisfying this condition, was to make the same vessel alternately a boiler and a condenser. Further

(*Cheverton's Gas Power Engine*, 1826.)

consideration confirmed me in the idea of the practicability of this plan, since the difference of temperature required to produce a great difference in the elastic form of the gas, is but a few degrees, when the minimum elasticity is already considerable. The project of an engine, as represented in the figure prefixed, was therefore substantially completed; it remained only to adopt a mode of alternately heating and cooling the liquid employed. Several plans suggested themselves, but I prefer, for its simplicity, its certainty, and the ease with which it can be regulated, the method which will be immediately explained.

"*Description of the Engine.*—The figure presents a vertical section, with this remark, that as all the vessels have a circular form, a horizontal section becomes unnecessary. It is proper to observe, that the disposition of the parts as represented, has been adopted solely for the purpose of bringing the whole into one view. The engine consists of a duplication of parts, *viz.*—*a a,* two refrigerators containing cold water; *b b,* calorators containing hot oil; *c c* alternators lined with wood, and filled alternately with the hot and cold medium. *d d,* generators, consisting of a cylindrical assemblage of capillary copper tubes, about half filled, at the minimum pressure, with the carbonic acid, or other liquid employed—they communicate with the upper end of *e e,* strong copper gasometers, lined with wood, nearly full of oil, at the minimum elasticity of the gas, but which, at its maximum, expels nearly the whole of it into the cylinder, *h,* in which works *i,* the piston. *l l,* solid wooden plungers. *n n,* pipes for a constant supply of cold water. *o o,* pipes through which gas is in the first instance introduced, and oil occasionally *injected,* in order to supply the waste at the piston rod—they are closed in a particular manner. *p p,* boards floating on the oil; (. . . . .), level of the water and of the oil; (- - - - -), level of the separation between the water and the oil.

"*Action of the Engine.*—One of the gasometers being nearly full of oil, and the generator attached to *it, with* the liquid contained therein, being reduced to the lower

temperature, the elasticity of the gas is then at its mini mum; but which will at all times be very considerable, especially if the carbonic acid, or the nitrous oxide, be the liquids employed; a flood of hot oil suddenly descends upon and surrounds the generator; instantly, an evolution of gas takes place, and continues till its density, and consequent elasticity, produce the pressure under which the liquid ceases to boil at the temperature to which it has attained. This increase in the elastic force of the gas will be in some proportion to the elevation of temperature, but differs, not only with the different liquids employed, but with the same liquid, according to the prior pressure under which it was placed. Meanwhile, the gas, pressing on the oil in the gasometer, causes it to rush into the cylinder, carrying with it the piston that works therein to the farther extremity. The duplication of the apparatus produces the return stroke, and thus a movement is kept up. But to effect the re-action, the elasticity of the gas, which now occupies nearly the whole of the gasometer, must be reduced. For this purpose, the generator is flooded with cold water, which rises from below, bearing up the hot oil on its surface, to the place from which it descended. The temperature of the generator and its liquid falls, the gas condenses rapidly on its extensive surface, its density as rapidly diminishes, it returns to its first elasticity, and the oil regains its former level in the gasometer. Again the water sinks, and the hot oil descends, and thus the same vessel becomes alternately a boiler and a condenser; in one case generating a gas, in the other a liquid. To force up the hot oil from the alternator into the calorator, in which it is heated, a plunger is immersed in the column of cold water contained in the refrigerator; this raises its level, and consequently the level of the column of water and oil with which it is in equilibrio. There is not the friction, concussion, or elaborate workmanship, which would attend a piston employed for this purpose. The specific gravity of the oil being less than that of water there will, of course, be a difference and a varying difference in the altitude of the two columns, when in equili-

brio, according to the well-known hydrostatic principles, but this is of no consequence. The plunger must be so proportioned, and immersed so deep, as to displace a body of water equal in volume to that of the oil elevated, besides what is required for the raising of its own level. Now it is obvious that here is an opportunity to regulate the power of the engine; for the less the plunger is raised, the less is the descent of the hot oil, and consequently less of the liquid is exposed to its influence; a governor, therefore, would be very properly applied to the movements of the plungers. If a greater power be required than when the governor is at the extreme limit of its influence, that is, when the generator is entirely surrounded with hot oil; it may be produced by bringing the lamps nearer to the calorator, or by lighting a greater number of them. If however the same velocity of action be not required to be maintained, the engine, possessing in itself a source of self-regulation, will increase in energy for the occasion; because the slowness of the strokes allowing a longer time for the heating of the liquid, its temperature will be raised to more than the ordinary degree, for this must be always less than that of the hot oil. The extent to which this enlargement of the power may be carried, and the facility with which it may be effected, is of great importance with respect to navigation, and will be duly appreciated by those conversant with the subject. The limits of this extension, and the safety of the engine, are points which will be discussed hereafter. It should be observed that the action of the plungers must be a little in advance of that of the piston, in order to give time for the heating and cooling of the *metal* of the generator.

"*Remarks.*—There is this peculiarity in the engine, that it has neither valves, cocks, nor pumps, nor any moving joint, except that of the piston and its rod; hence its simplicity, and consequently the cheapness with which it may be constructed. The room which an eighty-horse power engine would occupy, would not probably be more than a cubical space of seven feet dimensions, so far as the cylinder and its appendages are concerned. It would be quite

practicable to attach a guage to the engine, by which the pressure of the gas may be ascertained; and means are devised by the use of which the height of the liquid in the generator may be known. The introduction of the carbonic acid or other liquid employed, should be in the form of gas. For this purpose, the generator must be brought to a lower temperature than the gasometer, which will occasion the greater part to condense therein; that which may form in the gasometer will distil over, after the apparatus for producing the gas is removed. It is also for this reason, that there is no fear that an accumulation of the liquid will take place in that vessel during the working of the engine. To prevent condensation, however, in any hurtful degree, its interior is lined with wood, and a board floats on the surface of the oil. Another plan would be, to maintain the gasometer at the higher temperature to which the liquid is raised; but this is by no means advisable, if it can be avoided. The board is also of important use, in preventing the absorption of gas by the oil, during the greater pressure; which being evolved at the time of the collapse, would prove injurious, by diminishing the difference between the elastic forces. Oil is selected as the heating medium, because it is lighter than water, and has its boiling point so much higher. It is probable, however, that two hundred and twelve degrees is a temperature sufficiently superior to that to which the liquid will require to be raised, and such as will produce its almost instantaneous heating; if so, hot and cold water may be employed. From the relative position of the two mediums, little communication of heat can take place. The alternator is internally lined with wood, partly to prevent a loss of heat, but principally to preserve, as much as possible, the coldness of the water. In a locomotive engine, the water could only be occasionally changed; in the intervals a cooling process may be at work, and the plungers would perform the office of a pump."

Gas Motive Engine, by Lieut.-col. Torrens, of Croydon. 1830.

This is another very recently invented apparatus for obtaining power and motion, from the expansion of liquids obtained from condensed gases. The inventor observes, in his specification, that the chief difficulty which Mr. Brunel and others have met with, in constructing apparatus for obtaining power on this principle, was to construct vessels of sufficient compactness and strength, to prevent the escape of the gas, and at the same time to permit the motion of pistons, &c. The liquid of sulphuretted hydrogen, at fifty degrees, has been found to produce a vapour which exerts a pressure of seventeen atmospheres. Fluid carbonic acid, at thirty-two degrees, produces vapour exerting a force of thirty-six atmospheres. Nitrous oxide liquid, at forty-five degrees, produces vapour of fifty atmospheres' pressure; the vapour of ammonia, at fifty degrees, 65. atmospheres; muriatic acid, at fifty degrees, 40 atmospheres, and chlorine, at sixty degrees, 40 atmospheres. To resist such pressures, of course, very strong vessels, and compact materials, are essentially necessary, to prevent the escape of the subtle vapour.

Colonel Torrens's plan for this purpose consists of the following arrangement. On a furnace is placed a strong vessel or boiler, which is partly filled with the condensed liquid of the condensed acid, and partly by the vapour arising therefrom. This boiler he surrounds with oil, (or other suitable matter), contained in an exterior vessel, serving as a medium to convey the heat, and assisting in preventing the escape of the vapour. The working cylinder and piston are in like manner surrounded by another exterior vessel, containing oil under great pressure, and it is connected with the boiler and the condenser by passages and valves, similar to those used in steam engines. The condenser is surrounded by cold water, which liquifies the vapour after it has passed through the working cylinder, whence it is forced by a pump back into the boiler. The gas in the upper part of the boiler is forced through a pipe, into the working cylinder, on the alternate sides

of the piston, by the action of a powerful pump, on Bramah's principle.

As the difference of heat between sunshine and shade, is, under some circumstances, sufficient to work an engine of this kind, a *furnace* as before mentioned, in the ordinary conception of that term, is not required, but any convenient means of communicating a slight increase of temperature.

Patent Air Engine, by R. and J. Stirling, of Glasgow. 1827.

Messrs. Stirling's machine resembles the steam engine in the construction and application of many of its parts, such as the cylinder and piston, the reciprocating beam and parallel motion, and the fly-wheel and crank, as represented in Fig. 1. Motion is communicated to the piston in the cylinder, *o*, by alternately heating a portion of air connected with one side of the piston, and at the same time cooling that in connexion with the other. And this is effected by means of the air vessels *a a*, one of which communicates with the upper part, and the other with the lower part of the cylinder, through the nozles

m m, the pipe *n* forming the communication between one of the nosles *m*, and the top of the cylinder. Fig. 2, represents a section of one of the air vessels, whose sides are cylindrical, and top and bottom spherical. This air vessel, which is made of cast iron, and supported in the brick work by the projecting ledge *l l*, is furnished with a plunger, *c C c*. The top and bottom of the plunger is made of strong sheet iron, perforated with very numerous small holes, to admit the air. The interior of the plunger is filled with very thin plates of sheet iron, so bent as to prevent their flat sides from coming into contact, that the air may have a free passage between them. These are also perforated with small holes, which holes are placed opposite to each other, but so arranged as to cause the air to pass through the plunger in a zig-zag direction. The patentees state, that the interior of the plunger may be filled up with pieces of brick, gravel, or other granulated substance, instead of

the thin sheet-iron. The plunger is formed circular, to fit the top and bottom of the air vessel, when drawn up and down. The rim *c c* of the plunger, which moves in a cylindrical receptacle at the circumference of the air vessel, as represented, is not perforated as the other part. It is kept steady by the spring *u u*, consisting of a belt of thin sheet-iron, attached at its upper edge to the rim *c c*; a number of slits are made from the lower edge of the belt, to admit of its being bent outwards, to rest against the air vessel, and act as a spring. The plunger is also kept steady in its ascent and descent, by the plunger-rod *d*, passing through the stuffing-box at the top of its case, and the guide rods *g g*, which work in the guide cases *i i*, figs. 1, and 2. The guides are fixed to a ring *h h*, which is attached to the plunger and the plunger-rod, by the arms *f f*, four in number; they are supplied with oil, by an oil cup and stop-cock at the top of their cases. The top *e e* of the air vessel is flanged down in the manner represented at *k*, with a thin ring of sheet lead between the flanges, to keep the joining air-tight.

The lower part of the air vessels is heated by a fireplace under it, and its upper part kept cool by a current of cold air, by water, or by other means.

The plunger-rods of the air vessels *a a*, fig. 1, are attached by slings to the ends of the beam *v*, so that the motion which elevates one plunger in one of the vessels depresses that in the other.

When the plunger is raised, the cold air in the upper part of the air vessel will be heated in passing through the interstices of the plunger in its ascent, which has itself been heated on reaching the lower or hot part of the vessel, and during this time the air in the other vessel will be cooled, by passing through the interstices of the plunger in its descent, which has itself been cooled by reaching the upper or cold part of the vessel. These changes of temperature are further augmented, by portions of the air being alternately changed from the hot to the cold, and from the cold to the hot parts of the vessels, by the alternate occupation of the hot and cold parts by the plunger.

Now, as one of the air vessels is connected with the top, and the other with the bottom of the working cylinder *o*, there will be a motion produced on the piston, by the alternate application of the expansive force of heated air, and this motion is communicated to the beam *v*, through the piston rod and parallel motion *q*, and to the connecting rod at the other end of the beam, and the crank *r*, to the fly-wheel *s s*. On the axis of the fly-wheel is fixed an eccentric *l*, which communicates motion to the plungers in the air-vessels, through the system of levers 1, 2, 3, 4, and the beam *v*; and this motion is adjusted so that the change of the plungers shall be effected, whenever the piston reaches the top or bottom of the cylinder; thus applying to that end of the cylinder where the piston is, the hot air, which, by its increased elasticity, will drive the piston to the other end.

The diameter of the nosles, *m*, is one-fifth the diameter of the cylinder *o*, and one-fifteenth of the diameter of the air vessel *a*.

This engine is also furnished with an air-pump, the piston rod of which is shewn at *x*, for condensing air into the air reservoir *w w*. The air is permitted to pass through self-acting valves into the nosles *m m*, and thence into the cylinder *o*, or the air vessels *a a*, but not permitted to return from these vessels or the cylinder into the reservoir, which is also provided with a safety-valve for the escape of superfluous air, when more is pumped in than is necessary to supply the air vessels. The diameter and length of the stroke of the air-pump are half those of the cylinder, but this appendage is not required to be kept constantly at work.

The patentees state, in their specification, that any of the permanent gases may be employed, instead of atmospheric air. They do not claim, as their invention, the application of these bodies to produce motion; but merely the foregoing arrangement of machinery, for applying the elastic force of gaseous bodies to the production of motion

Patent Air Engine, by Messrs. Parkinson and Crossley, of the City Road, London. 1828.

This invention is another modification of machinery for rendering available to useful purposes the elastic force of air, in the construction of a motive engine. We have seen two models of these air engines at work, in which two distinct arrangements of the apparatus are introduced. The operations of heating and cooling the air are performed so rapidly by them, as to cause one hundred and fifty strokes of the piston in a single engine to be made per minute. The patentees not having yet completed their experiments on the large scale, we shall at present confine our attention to the specification of their patent lately enrolled, from which we make the following abridged extracts.

The power of this engine is derived from the heating and cooling of air, in an air-tight vessel, which the patentees term a *differential vessel;* a portion of this vessel being exposed to heat, and another to cold, externally. Inside the differential vessel is placed another of a similar figure, called a transferrer; this being moved from the hot to the cold parts of the differential vessel, and from the cold to the hot, alternately, transfers the air, and subjects it to the variations of temperature, as it passes along the internal surface of the differential vessel; and thus, by the expansion and contraction of the air, produces force for giving motion to machinery. The patentees do not claim to be the first discoverers of obtaining power by the alternate contraction and expansion of the air, by the processes of heating and cooling, but in the peculiarity of their method of effecting it. One of the most approved forms for this purpose we shall now proceed to describe, with reference to the accompanying drawings, figs. 1 and 2, which are upon a scale of two-thirds of an inch to the foot. Fig. 1, shows a front elevation of so much of an engine as is necessary to explain the invention; fig. 2, is an end elevation; and fig. 3, is a section of a differential

(FIG. 1.)

vessel and its transferrer, exhibiting also a mode of heating and cooling the differential vessel. The same letters in each figure, where they occur, refer to the same parts.

The differential vessel, *a a*, is of the form of a hollow cylinder, with close convex ends, of such a length as to preserve an essential difference in the temperature between one end and the other, and nearly one half of it

(FIG. 2.)

being subject to a hot, and nearly the other half to a cold medium. The vessel has a stuffing-box at the end *f*, and at the other end is an opening of pipe *l m*, or *l n*, for the purpose of forming a communication with the working cylinder and piston. The transferrer *b b*, is in this instance made a hollow vessel, air-tight, and so much shorter, as to leave a sufficient space in the differential

vessel for containing a volume of air, which, when expanded by heat, and passing through the pipe *l m* or *l n*, will also fill the working cylinder, and force the piston from one end of it to the other; the transferrer is also made, only so much less in diameter, as to admit of its being moved freely from one end of the differential vessel to the other. To one end of the transferrer is fixed a rod *e*, passing through a stuffing-box *f*, for the purpose of moving it from one end of the differential vessel to the other, thereby causing the air to pass in a thin stratum against its hot and cold parts, alternately; thus producing the force or power to be employed against the working piston. The rod *g*, (fig. 3,) which is fixed on the upper part of the differential vessel, is intended to guide the transferrer in its proper direction, by means of a tube, which is inserted in the upper end of the transferrer for that purpose, the lower end of which is made air-tight.

A differential vessel, constructed on this plan, may be applied to the purpose of working a single engine, acting only on one side of the working piston, after the manner of the well-known steam engines called single or atmospheric engines; but, in most cases, the patentees prefer the use of their differential vessels, as pointed out in the drawings fig. 1 and 2, directing the power alternately on each side of the working piston, after the manner of double steam engines. Motion is given to the transferrer by means of the eccentric *o*, in the shaft *p*, being connected with the beam *r*, which beam is connected to the rods *e*, of the transferrers, by the links *s s*. The working cylinder *n*, with its piston, side-rods, cranks, shaft, and fly-wheel and eccentric motion, are the same as those commonly used in steam engines, and therefore require no particular description. The pipe *l m*, communicates the differential vessel, No. 1, with the top of the cylinder; and the pipe *l n*, communicates the differential vessel, No. 2, with the bottom of the cylinder; the operation of the engine will be as follows:—Supposing the eccentric disconnected from the beam *r*, and the upper parts of the differential vessels heated, and their lower parts cold, and the transferrers of

the two differential vessels placed by hand in the situations shewn in the drawing, and the volume of air occupying the hot part of the differential vessel No. 2, and being increased in elasticity in proportion to its temperature, whilst the volume of air in the differential vessel No. 1, is occupying the coldest part, the working piston will be forced upwards, by a power corresponding with the difference of elastic force of the air in the two differential vessels; and when the working piston has been forced to the top, the situation of the transferrers should be reversed by hand, so that the air in the differential vessel No. 1, will occupy the hot part, and communicate its force to the upper side of the working piston, and thereby produce a returning stroke; and the eccentric being then by hand re-connected with the beams, the alternate expansion and contraction of the air in the two differential vessels, will keep the engine in motion; and thus, by working the transferrers the same way as the valves in steam engines, the engine may be either put in motion or stopped. For the purpose of heating the vessels, the patentees prefer the employment of inflammable gas, as it may be easily procured in all the principal towns in the kingdom; and by using compressed gas in portable vessels, the engine will be better adapted to locomotive purposes. As the street mains during the day-time, although charged, are generally charged at so light a pressure that the supply would be inadequate, the machine commonly called a gas-meter may be employed as a rotary pump for obtaining a supply, by connecting with its axis a train of wheel-work, with a spring or weight, to be wound up after the manner of clocks or time-pieces, giving to the meter a rotary motion. The mechanism of clocks being so generally understood, it is unnecessary to describe it here; it should, however, be observed, as the axis of the meter is below the surface of the water in the meter, one end of it should always project through a stuffing-box, in order to protect the mechanism from corrosion. The instrument called a *gas-governor* should be added to the meter, for the purpose of correcting any irre-

gularity in the flow of the gas. The patentees do not claim by this patent the gas-meter and gas-governor, nor their combination with clock-work, but *that combination* of the gas-meter with clock-work, or with the gas-governor, for the obtaining of a supply of gas from the street mains, which is made up by them with parts of the machinery of their engine, subject to the rights of the patentee of the gas-meter and gas-governor. The use of gas to this engine, and the application of the means described for obtaining a supply, enable the patentees to furnish a compact power engine, not requiring the constant attendance of a fire-man, and adapted to situations where sufficient space could not be appropriated for an engine requiring a boiler and coal-house, and where the smoke of such engines might be deemed a nuisance.

(FIG. 3.)

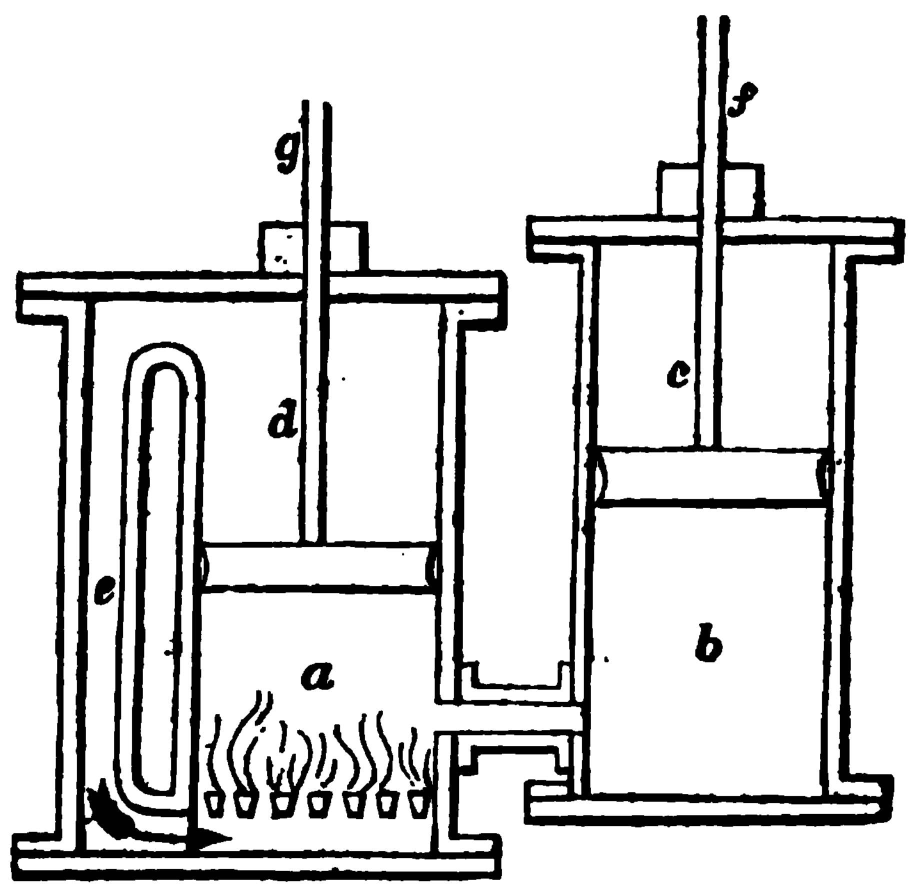
A mode of applying gas for heating the differential vessel, is shewn at fig. 3. *d d*, is a hollow ring, surrounding

the differential vessel, and communicating with the tube by which the gas is supplied; this ring is perforated, for the emission of jets of gas to flow, when ignited, all around, and against the differential vessel, or nearly so; *c c*, is an iron casing for directing the heat to the differential vessel, which casing is open at the bottom, for the admission of air, having also an opening at top, to serve as a chimney or flue; *h*, is an outer covering of polished metal, of about two or three inches more in diameter than the casing *c c*, for the purpose of lessening the radiation of the heat. The working cylinder *h*, may be kept hot by means of a current of heated air being conducted to it from the flues of the differential vessels; the arrangement for which being so easily understood, it is purposely omitted in the drawings. In fig. 3, *t t*, represent the differential vessel, as placed in a cistern of cold water, with a constant current running in at the bottom, *u*, against the differential vessel, and passing off at the top *v*. In situations where a sufficient quantity of water cannot be obtained for procuring the desired effect in this way, other well-known means of cooling vessels may be resorted to. To increase the power of the engine, it is proposed to increase the density of the air, by a common forcing-pump worked by the engines, and connected with the differential vessels; and as some leakage of air may be anticipated at the high pressures, the addition of the pump is necessary, and may be connected with the differential vessel by the tube *j*. This pump should be provided with any of the well-known means of adapting the length of the stroke to the loss of air by leakage. In starting the engine, this pump may be disengaged from the engine, and worked by hand, for charging the differential vessels with air of the intended density. A safety-valve should be connected with the differential vessels, and adjusted so as to let off any excess of air above that which is required. The speed or power of the engine may be regulated by increasing or diminishing the supply of gas, or other source of heat, by connecting a governor similar to that used in steam engines, with a valve or stop-cock in the pipe supplying the gas, or with

a damper in a flue, or with valves placed in the pipes *l m* and *l n*, regulating the ingress or egress of the rarified air to and from the working cylinder. The differential vessels and transferrers may be constructed upon the same principle in various forms, either cylindrical, cubical, or spherical; and they may be placed in vertical, inclined, or horizontal positions. The patentees mention several modifications in their specification, which it is unnecessary here to describe. The deviations in the shape will of course require different methods of applying the heat. The patentees do not confine themselves to the use of gas only, as the source of heat; in some cases, even steam may be adopted as a medium of communicating caloric; but a preference is given to the apparatus particularly described and delineated in the engravings."

Design for an Air Engine, by Dr. Arnott. 1829.

The following sketch of an engine, for obtaining the advantage of all the expansive force of heated air, as well as the force arising from the semi-explosions of the inflammable gas evolved from the fuel, is extracted from Dr. Arnott's Elements of Physics, vol. ii, part 1, treating of light and heat, lately published.



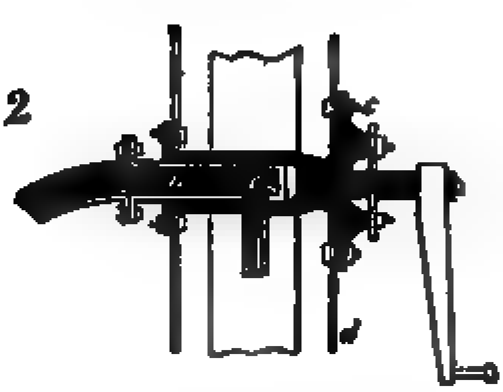
"If," says the designer of this ingenious apparatus, "we suppose a fire, *a*, to be placed in a grate, near the bottom of a close cylinder *d a*, and the cylinder to be full of fresh air recently admitted; and if we then suppose the loose piston, *g d*, to be pulled upwards, it is evident that all the air in the cylinder above the piston will be made to pass by the tube *e*, through the fire, and will receive an increased elasticity, tending to the expansion or increase of volume which the fire is capable of giving it. If there were only the single vessel *d a*, the expansion might be so strong as to burst it; but if another vessel, *b c*, of equal size, were provided, communicating with the first through the passage *b*, and containing a close-fitting piston *c f*, like that of a steam engine, the expansion of the air would act to lift the said piston, and by means of it work water-pumps, or do any other service which a steam-engine can perform. At the end of the lifting stroke of the piston *f c*, it might be made to open an escape-valve for the hot air, placed in any convenient part of the apparatus, and to cause the descent of the blowing piston, *d*, to expel this, while a new supply of air would enter by another valve into the cylinder above *d*. The engine would then be ready to repeat its stroke as before, and the working would be continuous, as in a steam engine."

SECTION VII.

STEAM ENGINES.

Under this head we include descriptions of a variety of steam engines, some of which are of a standard construction, and are, under various slight modifications, extensively used. A second portion consists of such as might have been included in Mr. Galloway's work, on account of their curious construction or instrinsic merit; and the third, embraces several novel inventions, that have become the subject of patent right, since the conclusion of the preceding history. They are arranged merely in the order of their dates.

2



(*American Steam Wheel.* 1808.)

The above cut represents, in section, the construction of a steam-wheel, invented many years ago in America; it derives its power from the tendency of light fluids to ascend, when immersed in those of greater specific gravity.

Fig. 1, exhibits a wheel divided into cells, and placed under heated mercury; or that mixture of eight parts bismuth, five lead, and three tin, which is fluid at the temperature of two hundred and twelve degrees, or, where waste of fuel and loss of speed are no great objects, placed under boiling water. Each of these cells is connected, by any appropriate means, with a steam pipe, so that each receives the steam, when at the bottom; the floating power then brings the other cells in succession to be filled with steam, and the wheel is then put into full action. Where the expansive force only is used, the steam escapes from the top of the trough; but if this be connected with a condenser and air-pumps as usual, the full power will be obtained from the metallic fluids. Each cubic foot of steam, in water, will give about sixty pounds of power; in the metallic mixture about six hundred pounds; and the velocity with which this supply can be afforded, and the height it can rise, will give the remaining elements for calculating the power of the engine As the steam will expand as it rises up in the buckets, no more should be allowed to enter, than will fill them, when at the top of the wheel. The metallic mixture is subject to oxidation by the hot water, in some degree; but it may be easily restored again, by melting the oxide under tallow.

When water only is used, the whole machine may be made of wood, in the form of a common bucket water-wheel; a steam pipe is introduced through the bottom of the trough, just under the side of the wheel where the buckets are inverted, when they become filled with steam in succession, and thus a stream of steam effects as much, bulk for bulk, as a stream of water.

Fig. 2. is a plan for admitting the steam into the pipes leading to the cells; *b* is a hollow axis, communicating with the steam pipe; *a* is one of the eight hollow arms through which the steam passes to the cells. *c* is a stuf-

fing box, and *d* an adjusting plate, with elastic packing. The steam tubes are of course covered up by circular plates, on each side of the wheel, to obviate the resistance in passing through the fluid.*

Lloyd's Portable Steam Engine. 1820.

The following engraving represents a very compact and effective engine, of eight-horse power, which has been employed in many of the public works about London, and recently in draining at the East London Water works.

Fig 1. Fig 2.

Fig. 1, is a side elevation, and fig. 2. an end elevation; the letters of reference apply to the same parts in each figure.

* Mechanic's Magazine, vol iv. p. 137.

a a, are the connecting rods; *b* the pump-rod; *c* cold water pump-rod; *d* hot water pump-rod; *e* throttle valve; *f f* induction and eduction valves; *g* piston rod; *h* fly-wheel; *k* crank; *l* eccentric, on the wheel to which the pump rods are attached when the engine is employed in draining; the dotted lines shew the parallel motion at the middle and bottom of the stroke; the arrangement of the levers is judicious, and possesses considerable novelty.

Portable High-Pressure Engine, by Alex. Christie and Co. Sheffield. 1824.

The present engine we have selected as a good example of an effective and compact high-pressure engine, and as

(FIG. 1.)

(FIG. 2.)

combining nothing in its arrangements, but what experience has found to be useful. Improved modifications will without doubt be made, but they will for the most part require to be tried by long-continued use, before they can be *established* as improvements. This engine is one of great simplicity, and is manufactured by persons of skill and experience in the construction. The drawings are taken from, and represent, an engine in Mr. Burdekin's anvil manufactory, at Sheffield. It is on a portable plan, and is calculated at only two-horse power, though it performs a greater quantity of work than that estimate denotes. It is employed in working three pair of large bellows, and in turning an enormous grindstone, used for

(FIG. 3.)

grinding the faces of anvils. The cylinder is seven inches in diameter. The engine is worked sixty-six hours per week, and consumes one ton of small coal or culm, (value on the spot 5s. 4d.) and one thousand two hundred gallons of water in that time.

Reference to Engravings.—Fig. 1, represents a side elevation of the engine. Fig. 2, a front elevation; and fig. 3, a view of the boiler and furnace.

a is the furnace door, *b* the furnace; *c* the ash-pit; *d* the boiler; *e* the stone float, (shown by dotted lines) for regulating the supply of water to the boiler; *g* a counter-balance to the float; *f* a flue, which returns the flame and heated air through the boiler; *h* the steam pipe, in which is the throttle valve *i*; *j* the side pipe, in which work the slide valves *k k*, moved by the rod *l*, attached to the eccentric *m*, in the shaft of the fly-wheel *n*. *o o o* are brass stuffing boxes; *p* the upper steam entrance to the cylinder; *q r* is the piston rod, working through the bridge

s, and communicating with the crank *t*, by the side rods *u u*, forming a very simple parallel motion; *v v* pedestals, supporting the main shaft, the revolution of which gives motion to a pair of bevel wheels, and thereby to the governor *w*, the expanding or collapsing of the arms of which, raises or depresses the collar *z*, and acts on the valve *i*, through the medium of the lever 1, and handle 2; 4 is the pump for supplying the boiler, through a feed pipe (not shown), worked by the rod 5, and eccentric 6; 7 7 are the metal cheeks of the frame. 8 is a metal foundation plate, under which is a small cistern (not shown), containing a day's consumption of water for the boiler. At the bottom of the side pipe, is an eduction pipe (not shown), from which the steam is discharged into the cistern, to heat the water for supplying the boiler, after the steam has performed its office in the cylinder. The periphery of the fly-wheel is round in its transverse section, and of cast-iron; the arms or radii are of wrought-iron, and are inserted into the former while casting. From the foregoing, it will be needless to describe the operation of the engine.

Improvement on the High-Pressure Engine, by Mr. J. Pattison, of Elswick Colliery, Newcastle-upon-Tyne. 1824.

In the abovementioned year, Mr. John Pattison introduced a method of applying, to the high-pressure engine, the plan of condensation used in the old atmospheric engine, but performed in a vessel distinct from the cylinder; the experiment was made upon the pumping engine of the Elswick Colliery, and proved eminently successful; a considerable saving in fuel being effected, and the pressure upon the boiler being greatly reduced.

Mr. Pattison had been extensively employed in the erection and management of steam engines, as they are used by the coal trade in the neighbourhood of Newcastle, where the Trevithick, or high-pressure engine, had been introduced at several of the collieries, for the purposes of pumping water and drawing coals. Some of those engines so applied, had been under his management for

some time, during which it frequently occurred to him that, instead of discharging the steam into the atmosphere, a considerable increase of power might be gained, by opening the discharging valves into a close vessel, and throwing in at the same time a jet of cold water, so as to produce, to a certain extent, a vacuum, which, of course, would so far assist the alternate sides of the piston, and be a proportionate real increase of power. The difficulty of getting quit of the air generated by condensation, without the use of an air-pump, presented itself to his mind; but some experiments which he made on what is termed high-pressure steam, together with his observa-

tions of the way in which the common atmospheric engine clears the cylinder of air, confirmed him that the idea was practicable, and, to a certain extent, beneficial. With this opinion, he mentioned the subject to his employer, Mr. Buddle, who thought it was at least worth trying; and with his usual liberality, and that constant encouragement which he always afforded to the improvement of science, requested him to make an experiment to determine its real merit, on the pumping engine at Elswick Colliery. The cylinder of this engine is thirty-one inches and a half in diameter, the piston making seven eight-feet strokes per minute, and delivering, at each stroke, sixty-four gallons, from a depth of fifty-five fathoms. Previously to making this experiment, the safety-valves on the boiler were loaded at 34.7 pounds per inch, and the boiler consuming sixty-nine hundred weight of coals in eight hours and a half. Mr. Pattison, after having completed and set to work the condenser, and attached a pump from the hot well, to feed the boiler (the engine going at the same rate, and performing the like quantity of work in the same time), the pressure on the boiler was reduced to twenty-seven pounds per inch, and the consumption of coals to forty-one and a half hundred weight, in the eight hours and a half. Nothing could be more satisfactory than this result, and, to prove the nature and extent of the vacuum, he attached a mercurial barometer to the condenser, and found it sustained a column of mercury, upon an average, of fourteen inches in altitude, its greatest height being about twenty-two inches.

Since carrying this into effect, Mr. Pattison says he has attached a double condenser to a machine for drawing coals, which brings to bank five score carves or baskets in an hour, from a depth of sixty-six fathoms, drawing two at a time. The result of this is equally satisfactory with the other, in having fully as much lessened the pressure per inch on the boilers, and considerably diminished the consumption of coals.

The prefixed drawing exhibits a single condenser, as attached to a pumping engine.

Like Mr. Watt's condenser, this one requires blowing through, previously to starting; but, in order to produce here the maximum effect, the injection must be so regulated as not to cool the condenser below the temperature at which the shifting-valve will be lifted, once every double stroke. In the pumping-engine above-mentioned, the quantity of cold water used for condensing each alternate stroke, is 2.75 gallons, from a jack-head cistern, twenty-two feet above the condenser. The upper discharging-valve, and the one for the injection, are both lifted at the same time; but the bottom discharging-valve is opened into the condenser, a little before the injection, which of course lifts the shifting-valve, expelling the air previously contained, at the same instant the injection is thrown in, when a vacuum is produced of not less than twenty-two inches of mercury.

It will easily be seen that the injection water, together with the condensed steam, pass down the sink pipe, and are discharged at the foot-valve at the same time the air is expelled. This valve is kept in its seat by a weight and lever, which are nearly equipoised, and which readily admit the discharge of the water into the hot-well.

Mr. Pattison observes, that it may be objected by some, that the vacuum is not constant and uniform; this, indeed, must necessarily be the case, from the manner in which the air is expelled from the condenser; but, as far as regards its action on the engine, it is not productive of the least irregularity, but, on the contrary, is a real and permanent increase of power, on the lowest estimation, of seven pounds per inch, and that, too, without the draw-back of any additional machinery, beyond raising the injection water and lifting the valve.

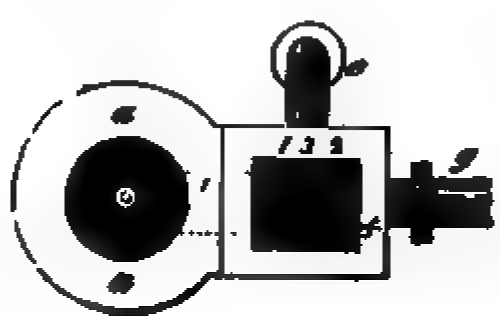
Patent Steam Engines, by W. Wigston, of Derby. 1824.

Two cylinders are about half filled with fluid metal, in which float two heavy cylindrical plungers, that are of rather less specific gravity than the fluid metal. Steam is made to operate alternately on the fluid metal in the

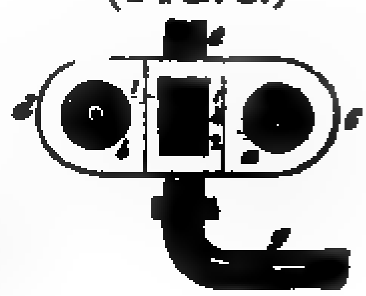
cylinders, raising one of the plungers, and allowing the other to descend simply by the force of its own weight; consequently, the power of the engine is equal to the weight of one of the plungers added to the difference of specific gravity between the other plunger and the fluid metal in which it is immersed. The following description is extracted from the specification of the patent.

Fig. 1, upon the annexed cut, represents a section of the engine, taken through the middle, to explain its internal construction. Fig. 2, is a horizontal plan of the

(FIG. 4.)



(FIG. 3.)



(FIG. 2.)

(FIG. 1.)

engine, supposing the covers of the various cylinders and levers to be removed, to facilitate the explanation. This engine is furnished with two separate weights or plungers, which are adapted to be moved up and down, similar to the alternating motion of a double-acting steam engine.

a and *b*, fig. 1, represent two cylinders, or cases of cast-iron, which communicate freely with each other at their lower extremities, in the manner of an inverted syphon; the upper extremities of these cylinders have flanges, which are bolted to the under side of a nosle-piece, *c d*, by which means the upper ends of the two cylinders are securely united together. The nosle-piece *c d*, has cavities or passages formed in it, for the admission and exit of steam to and from the cylinders; these passages form a right angle in the nosle-piece, and terminate in oblong slits or openings in the upper surface thereof, as represented by the dark spaces in the plan fig. 2, where the opening marked 1, is shown by the dotted lines to communicate with the upper part of the cylinder *b*; while the opening marked 2 is shewn by the dotted lines 2, as communicating with the upper part of the cylinder *a*; at the same time, the centre or middle opening marked 3, passes downward through the nosle-piece *c d*, and communicates, by the pipe *e*, directly with the atmosphere, when the engine is intended to be worked with high pressure; otherwise the pipe *e*, may serve as an eduction pipe to communicate with the condensing apparatus, such as is generally employed in steam engines. The openings 1, 2, 3, are covered by a sliding-valve 5, worked by a rack and sector, the spindle of the latter passing through the side of the steam-box *f*, of sufficient dimensions to admit of the sliding motion within it. The steam-box *f*, which is bolted to the nosle-piece, is furnished with a lid, secured by screw bolts, for the convenience of gaining access to the sliding-valve and apparatus contained in the interior of the box. *g* represents the steam pipe, which conveys the steam from the boiler; *h* and *i* represent two metallic weights or plungers, which are of such dimensions as to leave about half an inch space entirely round within the cylinders *a* and *b*; but the rings, or hoops represented in

the plungers, fit the interior of the cylinder so exactly, as merely to allow of their sliding easily up and down; the plungers have rods *k l*, fixed to them, which pass through stuffing-boxes *m n*. The operation of the engine is as follows:—

Suppose the plungers *h* and *i* to be at rest, and upon a level with each other in the cylinders; then suppose the curved part that connects the two cylinders, as well as the spaces round the plungers, to be filled to about the level of the dotted line *o p*, with any fit or ponderous metal, which is kept in a fluid state by the application of heat from a small furnace. In this situation, we will suppose the steam-box *f*, to be supplied with steam from the boiler, and the sliding-valve 5, to be in such a position that it would admit the steam to flow freely through the passage 2, before mentioned, into the upper part of the cylinder *a*; at the same time the sliding-valve 5, would establish a communication, through the passage 1, before mentioned, between the upper part of the cylinder *b*, and the eduction pipe *e*; in this situation the steam would descend by the sides of the plunger *h*, and would operate upon the surface of the fluid metal, to depress it in the cylinder *a*, and thereby cause a corresponding rise of the fluid metal in the cylinder *b*, which would pass round the plunger *i*, and destroy the equilibrium, by leaving the plunger *h*, unsupported by the fluid metal; and, at the same time, it would float or buoy up the plunger *i*, in a certain degree. Thus the plunger *h*, would be caused to descend with a force equal to its own gravity, and the plunger *i*, would be caused to ascend in the cylinder *b*, with a power equal to the difference of specific gravity which might exist between the plunger and the fluid metal, until they assumed the position shewn in fig. 1, at which instant the sliding-valve would be moved by its connexion with the engine in the usual manner, so as to reverse the order of communication between the steam passages, and thus admit the steam to flow from the steam-box *f*, into the upper part of the cylinder *b*; and at the same time to establish a communication between the upper part of the cylinder *a*, and the eduction pipe *e*; in this state, the steam would

exert its elastic force upon the surface of the fluid metal in the cylinder *b*, and cause it to descend and rise in the cylinder *a*, leaving the plunger *i*, unsupported, and buoying up the plunger *h*; by which means the plunger *i*, would descend by its own gravity, at the same time that the plunger *h*, would ascend, the steam escaping from the upper part of the cylinder *a*, through the eduction pipe *e*; thus a continued action may be kept up, by the alternate ascent and descent of the two plungers, which, by the rods *k* and *l* being connected, either by racks upon the said rods working into the opposite sides of the periphery of a toothed wheel, as shewn by the dotted circle *q*, in fig. 1, or by the rods *k* and *l* being attached to separate working beams, furnished with connecting rods and cranks, in the manner practised in other steam engines.

Note.—If the eduction pipe *e*, was connected with the usual condensing apparatus, the engine would be capable of performing its work with steam of a less degree of pressure, since the atmospheric pressure would always be removed from the surface of the fluid metal in that cylinder in which it was rising.

Fig. 3, represents an engine adapted to operate with one plunger only, producing the effect of a single-acting steam engine, such as are in general use for pumping or raising water. *a a* is the internal cylinder, which is formed with a close hemispherical bottom at *c*, and is cast or otherwise securely connected with the interior cylinder *b b*. The interior cylinder is formed open at bottom, so as to communicate freely with the annular space *c c*, which is left between the two cylinders; this space ought to be equal in area to that of the cylinder *b b*. *h* represents the plunger, of such dimensions as to move easily up and down within the interior cylinder, as described in the former engine; *k*, the plunger rod, sliding through a stuffing-box *m*. *f*, the steam box, containing the sliding-valve 5, for distributing the steam, worked by a rack and sector; *g*, the steam pipe, proceeding from the boiler to the steam box *f*. The passages for the steam are shewn by the dark parallelograms in the plan fig. 4, where the

opening marked 1, is represented by the dotted passage 1, as communicating with the upper part of the interior cylinder *b b*, and the opening marked 2, communicates with the annular space *e e*, between the two cylinders before-mentioned; this passage is seen more distinctly in fig. 3, as also the centre passage 3, which communicates directly with the exit pipe *e*, and condensing apparatus. When such is employed, the operation of this engine would be as follows:—

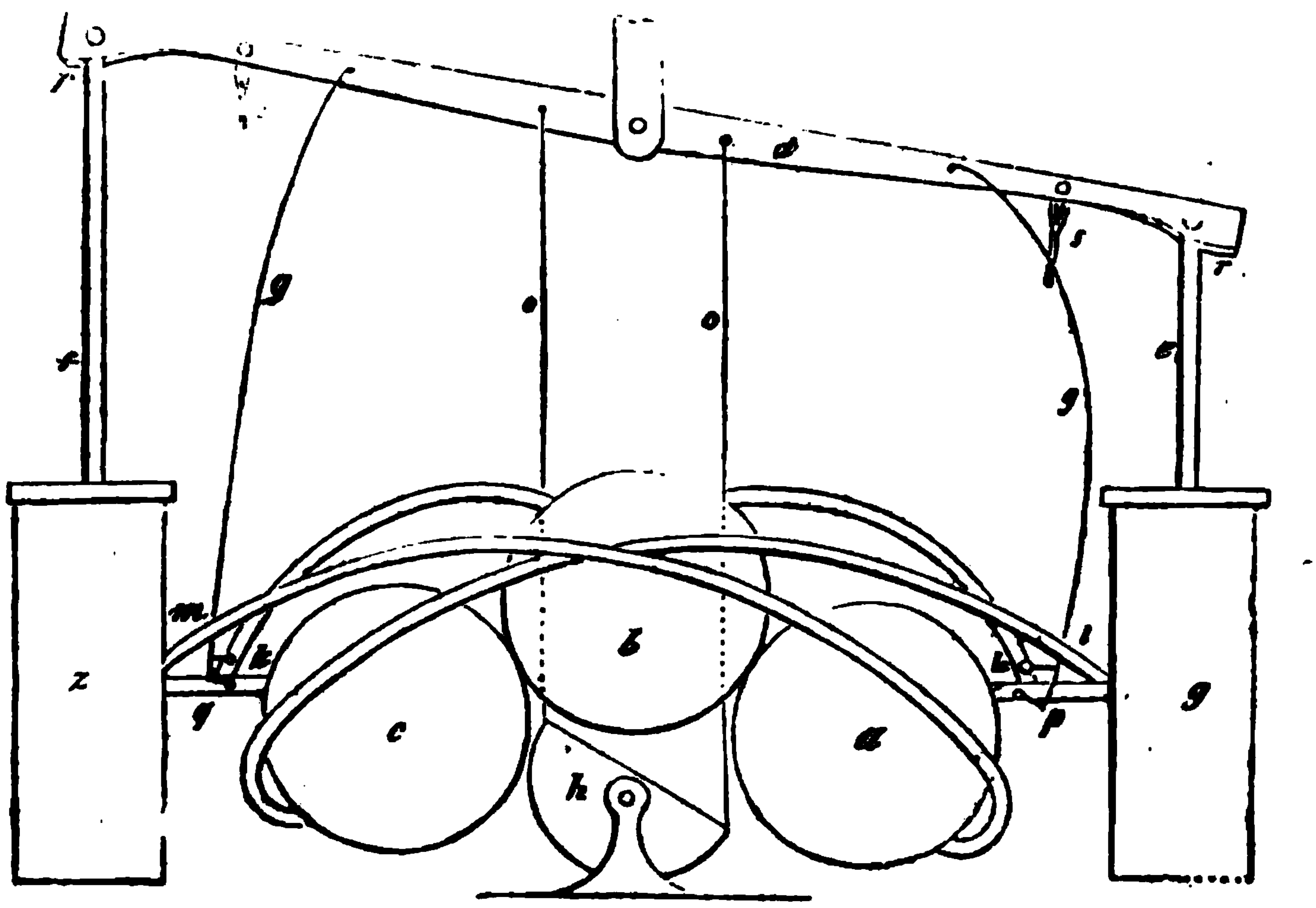
Suppose the plunger *h*, to be in the position represented by fig. 3, and the lower part of the cylinder to be occupied by the fluid metal; the sliding-valve 5, being in such a position that the steam would float freely through the passage 2, into the annular space *e e*; at the same time that the upper part of the interior cylinder *b b*, had a free communication with the condensing apparatus, through the eduction pipe *e*; in this situation, the elastic force of the steam would operate to depress the surface of the fluid metal in the annular space *e e*; at the same time the atmospheric pressure being removed from the surface of the fluid metal within the interior cylinder *b b*, it would be caused to descend in the annular space *e e*, and consequently to rise within the cylinder, until the weight of the column of fluid metal became superior to the weight of the plunger *h*; in which case the plunger, with its rod *k*, would move upwards, and carry one extremity of the working beam of the engine along with it, so as to prepare the pump, which is supposed to be at the opposite end of the beam, for making an effective stroke. As soon as the plunger *h*, arrives at the top of the cylinder, the motion of the sliding-valve changes the direction of the steam passages, causing the steam to enter the upper part of the cylinder *b b*, at the same time a communication is opened between the annular space *e e*, and the condensing apparatus, in which situation the steam would press upon the surface of the fluid metal in the cylinder *b b*; at the same time, the atmospheric pressure being removed from the surface of the fluid metal in the annular space *e e*, the fluid metal would be caused to ascend in the cylinder *b b*,

and rise within the said annular space, thereby leaving the plunger *h*, unsupported, which would then descend by its own gravity, and carry the end of the working beam along with it, so as to produce an effective stroke of the pump, and be capable of raising a column of water, equal in weight (upon the pump bucket) to the plunger. Thus a reciprocating action of the plunger may be kept up as long as a supply of steam is furnished from the boiler. The most advantageous method of keeping the metal in a fluid state is, by carrying a flue round the lower part of the cylinders containing the metal, this flue being a continuation of the engine-boiler flue, by which means any degree of heat that might pass off from the boiler flue is advantageously employed.

It will be observed, that there is almost a total absence of friction in the cylinders of this engine, which will, probably, render it serviceable as an engine of small power for raising water.

Patent Steam Engine, by the Rev. Moses Isaacs, of Houndsditch, London, 1824.

This invention consists in a mode of working a steamboat engine by means of three boilers, in such a manner



that the steam, after operating in the engine, is returned uncondensed into the boilers, and is thus worked continually over again. This ingenious arrangement is thus described in the specification.

"*a b c* are three boilers, *b* being placed upon *a c*; *d* is a beam, made in the form of a scale beam. *e f* are the piston rods (made hollow) with rollers at the top, working in the gutter or groove *r r*; near the ends of the beam *d*, connecting rods, *s s*, are suspended to the same beam, which give motion to the machinery; *y z* are two cylinders, *p p* are feeding pipes, passing from the boilers *a b* into the cylinder *y*; and *q q* are also feeding pipes, passing from the boilers *c b* into the cylinder *z*. This method of conducting steam is applicable to large vessels on water, or to engines on land; but for small vessels it is advisable to conduct the steam through pipes from *b c*, into cylinder *y*, and from *a b* into cylinder *z*; otherwise, the sudden forcing of the steam from the boilers *a b*, would cause a small vessel to rock. *l* is a pipe from the cylinder *y*, near the bottom of the boiler *c*, to recover the steam from the cylinder into the boiler *c*; *m* is also a pipe from the cylinder *z*, into the boiler *a*, instead of the usual means of condensing it.

"*h* is an oven, or trough, or grate, made in the form of a half-cylinder, moving from side to side by means of the rods *o o*, suspended from the beam *d*, (acting in points or centres); the ordinary grates or ovens may be used by applying shades to exclude the heat from the boiler *a*, whilst acting against *b* and *c*; in the same manner from *c*, when it is acting on *a b*, and thus continually having two boilers acting against one. *g g*, are two springs or rods, from the beam *d* to the cocks *e e*, on the feeding pipes *p p* and *q q*. The fire, acting on the boilers *a b*, causes the steam to lift the piston *e*, and consequently depresses the piston *f*, and forces the steam from the cylinder *z* into the bottom part of the boiler *a*, through the pipe *m*, and (vice versa) on the other side before described; any flame or heat may be used, by means of the moveable fire or shade."

This plan has been deemed worthy of a place here, not so much from an idea that in its present form it will be found to answer the purpose for which it is intended, (for the effect of the vibrating furnace on the boilers *a b* and *c* will not be sufficiently quick in communicating heat to the one, and abstracting it from the other, to afford an available power of any value,) as from a desire to furnish the almost numberless ingenious persons whose attentions are devoted to the improvement of the steam engine, with hints respecting an application, which to them may suggest practical plans of much importance.

Patent Steam Engine, by Messrs. Bower and Bland, of Leeds, Yorkshire.

This invention is intended as an improvement upon "such engines as condense out of the cylinder." It consists of a cylindrical condensing vessel, surrounded by another air-tight vessel of the same figure, but of a larger diameter, and, of course, leaving a space between it and the first. From the bottom of the first vessel a tube descends through the second, thirty-four feet, into a shallow cistern, and has there a valve on one side of its lower end, opening outwards; and into the top of the same vessel the tube, which carries off the steam from the working cylinder of the steam engine, enters a few inches, leaving a small space between its circumference, and the aperture by which it enters, for the passage of cold water, while it is joined air-tight to the external vessel. To produce the condensation necessary in the internal vessel, and in the lower tube, a constant stream of cold water, of a regulated extent, is to be made to pass through the space between the two vessels, and over the top of the internal one, by the narrow annular aperture between it and the steam pipe, down into the lower tube, where, besides condensing the steam which has entered into it, and the internal vessel, it is intended to act by hydrostatic pressure, superior to that of the atmosphere, in forcing out the water condensed from the steam, along with itself, through the lower valve.

The patentees purpose to produce the supply of cold water for the design mentioned, from a cistern below the level of the condensing vessel, by a tube rising up from the former, into the bottom of the space between the two vessels, which forming, with the long tube before mentioned, the two legs of a syphon, will, by the well-known principle of that instrument, convey the water upwards, over the top of the internal vessel, as required.

The tube of supply rises from near the bottom of the upper cistern, and from it at that part a pipe, furnished with a cock, passes across to the long descending tube; it has itself also a cock at its lower end, to regulate the supply of water which is to enter into it from the cistern. The use of this cross pipe is to set the apparatus to work at the commencement of its operations, which is effected (after having filled the vessels and tubes with steam, by opening the communication with the steam pipe, and having thereby blown all the air out of the apparatus) by opening the cock of the cross pipe, when the water will run directly from the cistern into the long descending tube (which has an enlarged cavity a little below the entrance of the cross pipe, to increase the effect of the cold water) where, and in the lower part of the long tube, coming in contact with the steam, it will instantly condense it, cause a vacuum, or an approximation to one in the vessels and tubes, which, on again closing the cock of the cross pipe, will oblige the water from the cistern to rise through the ascending tube, (its entrance at the bottom of the long descending tube being prevented by the valve placed there for that purpose,) fill the vessels and tubes, and thereby set the syphon principle to work, to produce a stream round the cistern, through the vessels and tubes, into the conduit or sewer at the bottom of all, which stream being regulated by the cock of the ascending tube, so as to be just sufficient for the condensation of the steam which meets it in the internal vessel, will, in the opinion of the patentees, cause that approach to a vacuum in that vessel, which it is their intention to produce.

As a variation from this plan it is stated, that where a

supply of water can be obtained above the level of the condensing vessel, a descending tube may be placed for its conveyance into the bottom of the internal vessel, instead of the ascending one from the lower cistern. Another variation, of less consequence, consists in forming a neck to the top of the internal vessel, enclosing the steam tube as before mentioned, but having holes in its sides, for the passage of the cold water into the internal vessel, instead of the narrow annular interval between that tube and the top of the vessel, first directed for that purpose.*

The object of this invention is unquestionably important, but we fear the apparatus is at present incomplete, as there does not appear to be any means provided for removing the air extricated from the water and steam.

Patent Steam Engine, by Samuel Wellman Wright, of Lambeth, Surrey. 1825.

This is a rotary engine, and consists of a flat hollow cylinder, placed vertically, within which another concentric cylinder is made to revolve on an axis, by square valves or flaps, which are fastened to it by close-jointed hinges, and open from it at right angles, so as to occupy the space between it and the external cylinder, during about three-fourths of its revolution, and which are gradually closed in succession by an inclined plane, that projects internally from the rim of the external cylinder, extending about a fourth of its circuit, and coming close to the revolving cylinder at one end, where it forms a stop-piece, that fills up the interval at that part between the two cylinders; beyond which stop, the induction steam pipe enters into the external cylinder, while the eduction pipe, that conducts the steam to the condenser, passes out near the other extremity of the inclined plane. The flaps, when closed, lie in hollows, made to fit them in the rim of the revolving cylinder, and have flat pieces of brass placed on studs, near to their edges; which, being pressed outwards

* Repertory of Patent Inventions.

by springs that lie behind them, form what may be called a metallic packing, at three of their sides, while the third side is closed by the accurate fitting of the hinge, so as altogether to prevent the steam passing through between the valves and the cylinders in any part. The passage between the revolving cylinder and the stop is made steam-tight, by a thick piece of brass, that fits close to the rim of the first, and is received into a cavity of the latter, in which springs are inclosed, that press it out against the revolving cylinder; and the two cylinders are made to fit steam-tight, at their circles of contact, by two flat brass rings, one of which is fastened to each side of the revolving cylinder, by screws inserted through slots, which admit of its being moved outwards towards the fixed cylinder, and, being divided into two pieces across its diameter, flat wedges, which are pressed by springs into the lines of its junction, from the side next to the axle, tend always to press it outwards against the inner rim of the external fixed cylinder, and keep the steam from passing by it, notwithstanding its gradual wear.

The valves or flaps are made to rise out of the cavities that contain them, after they have passed the inclined plane, by pieces that proceed from their hinges, nearly at right angles to their backs, which point towards the axle when they are closed, and which come in contact with a roller, whose axis is fastened to the side of the fixed cylinder, when the flap has completely passed the inclined plane; which roller, by pressing these handles backwards, obliges the flaps to rise upwards across the annular cavity between the two cylinders, and constitute that opposition to the steam which causes the internal one to revolve, and turn round the machinery that is connected with its axle.

The Editor of the Repertory of Arts (from which work the foregoing account is chiefly extracted) observes, that this engine "very much resembles" Mr. Walter Foreman's, (described at page 272), but that the latter is inferior to it, on account of no adequate method being provided for making the various moving parts steam-tight. The writer evidently alludes to the omission of packing to the flap

valves, by Captain Foreman, the *conical* form of which he does not perceive renders packing unnecessary; and it is on this *peculiar* form of the valves and case the Captain founds his patent right. Mr. Wright's engine has a greater resemblance to several other engines that preceded Captain Foreman's in our account, wherein similar valves are used, possessing the same common defect, or liability to leakage at their joints, which it is scarcely possible to prevent. See Cooke's, page 104; Chapman's, page 207; besides several others. One of the best features in Mr. Wright's engine, is, his mode of packing the crevice between the revolving and fixed cylinders, by the brass segments, which are pressed asunder by wedges and springs, forming a new and useful application of the principle of Barton's metallic piston.

Patent Steam Engine, by Captain Halliday, of Ham, Surrey. 1826.

The steam engine described in the specification of this patent, is of the rotary species, and consists of a wheel, having a deep rim, that passes through a case of larger dimensions, which embraces a portion of its circumference; and from that part of it which is within the case, valves are made to open, that fit the case accurately, and, by receiving the action of the steam, cause the wheel to revolve. The rim of this wheel is much deeper from the circumference towards the centre, than its thickness; which latter must, however, be sufficient to contain the valves within its sides, so that, when they are closed, no part of them may project beyond their limits; these valves turn on a pivot, that goes through their middle, in the direction of the radii of the wheel, and passes through the substance of the rim, towards the centre of the wheel, for a purpose that will be explained: the valves, when turned round, so as to be at right angles with the rim, must fit the case exactly; and, for this purpose, are made in the shape of its transverse section, which, as shown in the drawing of the specification, is a parallelogram, a little rounded at

top, and about half the depth of its breadth; but, as the patentee states, many other shapes for the transverse section of the case and valves, will have a similar effect; again, when the valves are turned back, so as to lie in the direction of the rim, the cavities in which they are to lie must be so fitted to them, and they to the cavities, that they may entirely occupy and close them up, so as to present a smooth and uniform surface externally, exactly coinciding with the face of the rim. The case encloses one-third of the rim, and is made in two equal pieces, separating in the plane of the rim, and having flanges at their edges, by which they may be jointed together closely, with screws and nuts; in which line of juncture they inclose a segment of a flat ring, made of brass, of the thickness of the rim, but which is of a less depth than the flanges, so as to admit the part of the edge of the rim that extends above the valves, to enter between the flanges, in order to make the juncture of the parts more accurate; this brass segment can be taken out and refitted, when either it, or the edge of the wheel, wears so as to cause an imperfect conjunction.

As it is necessary that the inside of the case should be exactly curved to correspond with the rim, the patentee directs that, for this purpose, two other similar pieces should be joined to each of the sides, by the flanges at their ends; and, as each consists of the third part of a ring, the whole three will form an entirely hollow ring, which may then be turned by the lathes used for work of large dimensions, so as to have its internal cavity turned out perfectly circular, true, and even; and, after the pieces are again separated, two of them will form the case. The flanges at the ends of these pieces, though essential for the purpose just mentioned, are intended for fastening on the covers that close the two ends of the case, and through apertures in which the rim of the wheel passes; which apertures must be made to fit it, so as to render it steam-tight; these apertures, which will thus be in the shape of the transverse section of the rim, are to have pieces projecting outwards from them, in an angle of about forty-five degrees at each side; whose use is to bring the edges of the

valves within the cavities of the rim, so as to pass through the apertures without obstruction, should they by accident come into such a position as would render these guides necessary.

The parts of the case that are below the valves, or between them and the centre of the wheel, fit accurately to the sides of the rim, so as to prevent all escape of steam. The valves are made to turn round, to be at right angles with the rim, and back again, to lie flat within its substance, by the lower part of the pivots, which we before stated passed through the inner part of the rim towards the centre; from this part of the pivot of each, an arm projects, at right angles to the valve, having a roller at its extremity, which, as the wheel turns round, comes in contact with a guide-bar, fixed to the frame in which the wheel turns, which bar is curved sideways, as well as in the direction of the arc of the rim, and gradually, as the rim turns, pushes the arm into the plane of the rim, and by this causes the valve to turn round at right angles to it, and occupy the transverse section of the cavity of the case; and this turning out of the valves is made to take place by the proper position of the guide-bar, just as they enter within the case; and they are brought back again to their first positions within the rim, by a similar guide-bar at the other side of the wheel, which acts on other arms placed at right angles to the first, or in the plane of the valves; they may also be made to go back into their places by springs, when they have passed the first-mentioned guide-bars, that cause them to expand, and keep them open as long as is required. The case is represented as being fixed to the upper portion of the side of the wheel, and in a vertical position, as the latter of course is also; and the pipe by which the steam enters into it from the boiler, is fixed to the cover of the upper extremity, and when the steam is of the ordinary pressure, and a condenser is used, a similar pipe passes from the cover of the lower end of the case to that condenser; but when highly-compressed steam is used, then the latter pipe is necessary, and the lower cover itself may be removed.

The number of the valves may be regulated by the

fancy of the engine maker, provided it be such that two of them at least may always be at the same time within the case, as the wheel revolves; and their edges may be grooved so as to contain common packing, or metallic packing expanded by springs. The wheel itself turns on an axle, supported by sockets attached to a firm frame, resting on six pillars, two of which stand directly under the sockets; one of the ends of the axle is prolonged beyond the frame, to form a connexion between the wheel and the mill machinery, which it is intended to work; and four, six, or more arms or spokes, join its rim to the nave or centre piece, through which the axle passes.

A cistern of hot oil, made to fit the rim of the wheel, is so placed as to receive its lower part, and being kept at the same heat as the steam used, or a little above it, by a furnace properly disposed beneath it, will both maintain the wheel at such a degree of temperature as will prevent its having any tendency to condense the steam, and will at the same time keep the rim and valves always lubricated, so as to pass the case with facility. The boiler, condenser, and every other part necessary to complete the engine, are of the commonly approved construction.*

This invention of Captain Halliday's reflects great credit upon his inventive talents; the mode of opening and closing the valves for exposing them to, and withdrawing them from the action of the steam, is highly ingenious; and it is much to be regretted that so beautiful an operation cannot be efficiently performed for any considerable time, on account of the difficulty of preserving the essential parts steam-tight, and that the superior quality of workmanship required to make such a machine in the first instance, must prove an obstacle to its adoption.

Although foreign to the principal object of this work, we may here mention that we have seen a pump of the above construction operate well, with an economy of power; the valves in which, not touching the sides of their case, enabled a rapid motion to be given them, without any friction in those parts.

* Repertory of Patent Inventions, vol. iii.

Patent Compound Rotary Engine, by J. Eve, of London. 1826.

This invention consists in some peculiar and ingenious arrangements for the employment of steam, twice over, in two distinct *rotary* engines; in the first of which the steam is used at a high pressure, and in the second allowed to expand to low pressure. In a communication to the editor of the Register of the Arts, the patentee observes,

"The difficulty of availing ourselves of using steam twice, that is, first as high pressure, and then in a condensing engine to any extent, is sufficiently apparent from the following considerations. It appears from Mr. Woolfe's experiments, that steam heated to balance six pounds to the inch, will expand into six times the volume under atmospheric pressure, at 20 pounds to 20 times, at 40 pounds to 40 times, and so on.

"Working with comparatively so low a pressure as 40 pounds to the inch, it would be found extremely inconvenient to use two engines whose capacity were as one to forty, and if not impossible, would appear ridiculous, if steam of 200 pounds elasticity (which is quite common in the United States) be used, as the second engine would be twice the capacity of the first, which in this extreme case would at least have a disproportionate appearance. All reciprocating engines will have to contend with this inconvenience, or, rather, can only avail themselves of a partial advantage from using high and low steam, as they have to work stroke for stroke. With my rotary engine, the full benefit of this principle may be appropriated; as the engine that acts by high pressure may be smaller in the first instance, and then the engine for low pressure may be made to revolve so much faster than the first, as to allow of the full expansion of the steam before it is acted on, for the velocity may be carried to any extent required, without inconvenience."

The following figure represents an elevation of Mr. Eve's "compound steam engine." *a* is the furnace, con-

taining the steam-generator, or boiler; *b* is the dome on the top of the steam receiver, with the steam pipe *c*, and safety apparatus *m*; *d* is a cock and pipe, through which steam is admitted to the high-pressure engine *e*; after having acted upon it, the said steam passes into the low-pressure engine *f*, constructed on the plan described at page 275, on a larger scale, so as to allow the steam to expand, and then act upon it at low pressure. *e* and *f* have pinion wheels of an equal pitch, gearing into a spur-wheel *g*; these wheels determine the power given to each engine, by regulating their motion with reference to the power required from each. The steam finds its escape at *x*, into the condenser *h*. The condensed steam or water runs through pipe *i* by its own gravity, towards the two revolving cocks, whence it is conveyed back to the feeding pipe in the steam-generator. *v* is an engine on the before-mentioned plan, having two induction and two eduction pipes, which engine serves as a pump in this particular situation. *w* is the service-pipe from the well, leading into the refrigerator; *x* receives the water in the refrigerator, and carries it downwards. *p* is the bellows for blowing the fire, by means of a band round the axle, connected with a pulley. *o* is the valve and lever of the bellows, connected by the rod *n*, with the safety appa-

ratus; t and u are pulleys, connected by a band, to give rotatory motion to pump v, but any other contrivance may be used; l is a cock, which is only opened before the engine is set to work, in order that the air may be driven out of the pipes and condenser by the steam; the cock may then be shut, and the engine set to work; y is a pipe, leading from the safety apparatus to the condenser; therefore, if an engine be so contrived, and the boiler be once filled with water, the same water will answer for working the engine, as long as the pipes remain sound, or at any rate with very little loss of water.

Patent Steam Engine, by Mr. Thomas Peck, St. John Street, London. 1827.

The principle of the two methods for producing revolving steam engines, described in this specification, consists in making the main cylinder of the engine revolve, by the action of its piston rod on a fixed axle, placed eccentrically to that round which the cylinder performs its revolution.

In the first method, this is effected by suspending the main cylinder on hollow axles, that project at right angles from the middle of its sides, opposite to each other, and through which the steam is conveyed from the boiler, and passes to the different ends of the cylinder alternately, by pipes that run along the sides of the latter; and again, by open air, (according as the engine is of the low-pressure or high pressure species,) by the operation of a sliding box-valve, which is moved by an eccentric wheel, that is turned by the revolving machinery. The cylinder being thus prepared, a toothed ring is fixed vertically round each of the hollow axles, with its centre the distance of a quarter of a stroke of the piston from them, and is there fastened immoveably to the frame-work that supports them, while a frame, worked by the piston-rod in its own plane, carries two vertical-toothed wheels at each of its extremities, the teeth of which interlock with those of the toothed ring at its opposite sides; and connecting rods

being passed from the centres of these wheels to pivots in the rim of a fly-wheel that turns round the same centre as the cylinder, it follows, that when the piston-rod enters the cylinder, the two wheels at its farther end will be forced along the peripheries of the fixed rings; and as these are eccentric to the hollow axles of the cylinder, will (by bringing the extremities of the latter alternately nearer to and farther from their centres, while at the same time they are drawn and pushed successively by the piston-rod, towards the hollow axles and away from them) cause the cylinder to revolve round its axles, for half a revolution, from the combined effect of the two motions acting angularly to each other. In like manner, when the piston-rod is pushed out from the cylinder, the two wheels at the opposite end of the frame that moves with it, will, by acting on the fixed wheels, in the same manner as the others just described, have a similar effect on the cylinder, make it perform another half revolution in the same direction, and thus cause it to complete an entire revolution; the velocity of this is rendered equable and uninterrupted by the action of a fly-wheel at each side, which, by their momentum, continue the turning of the cylinder, when the piston-rod moves in the line that passes through the axles and the centres of the rings, and when of course the force would otherwise be expended in injuriously impelling the two centres, either towards or from each other, according to its direction; in like manner as takes place with the crank and fly-wheel in common steam engines.

The two pair of wheels at the end of the piston-moved frame, are attached to these by axles that pass through points in them, one fourth of the piston stroke removed from their centres, in order that they may correspond with the eccentricity of the fixed rings; which being, as before noticed, also a quarter-stroke eccentric, the two eccentricities added together are equal to half a stroke, at each passing of the revolving and fixed cylinders; and as this occurs twice in each revolution of the cylinder, the four quarter-stroke eccentricities thus keep pace with the

motion of the piston, so as to produce one revolution for each stroke.

There are thus six wheels employed in producing this motion, all of which are of the same size; two central wheels that are fixed, and four that revolve round these, three of which are at each side of the cylinder; the piston-moved frame, that carries four of these, (two at each extremity,) has a ring at each side, that encloses the fixed toothed-wheels, and is so much larger than them, as to allow for their eccentric positions, and escape coming in contact with them in any part of the revolution; the two sides of this frame, and the three toothed-wheels adjoining to each of them, lie between the cylinder and the fixed frame that supports its hollow axles.

In the second method for producing the revolution, two or more steam cylinders are fixed by gudgeons between the peripheries of two fly-wheels, at equal distances from each other, with their piston-rods extending to an axle, eccentric to that of the fly-wheels a distance of half a stroke; the gudgeons and the axle of the fly-wheels are hollow, and tubes pass between them, connected to the former by turning joints, made steam-tight, like those of cocks; the steam is conveyed to the cylinder by these tubes, and by others that run along their sides to their extremities, and is again passed off, either into the open air or into a condenser, by the same tubes, or by others similarly placed at the opposite sides of the cylinders; the passages between these tubes and the boiler and condenser are opened and closed by sliding box-valves, moved as required by an eccentric wheel, turned by the wheel-work of the engine. The axles of the fly-wheels, in both methods, afford proper situations for the primary wheels, that are to convey the motion to the machinery, for the working of which the engines are required; and when the engines are to be first put in motion, the fly-wheels must be turned by hand for some distance, until the force of the steam commences its action upon the revolving apparatus.*

* Repertory of Patent Inventions.

Patent Steam Engine, by R. Stuart Meikleham. London, 1827.

This invention consists in a method of generating vapour or gas within the working cylinder itself, produced by the application of a heated fluid medium inside the piston. We have reason to believe that the project was never carried into effect, except in a small model; nevertheless, it is sufficiently novel and specious to demand a description in this work. The only publication heretofore containing any notice of this patent, is the London Journal of Arts, from whence we extract the following, though not very clear account; the writer of which, however, complains that the enrolled specification of the patent is very deficient in clearness, a quality, which no one who knows its highly-talented author* would suspect.

"A cylinder, of the kind commonly applied to steam engines, is to be employed, in which a piston works up and down, as usual. In the upper part of the cylinder a long tube is to be inserted, within which the rod of the piston slides. The piston is intended to be made hollow, with three horizontal compartments, if we understand aright, and with valves opening outwards. The rod of the piston is to be hollow, and, indeed, have several small tubes or passages extending along it, from end to end.

"One of the tubes in the piston rod is designed to conduct melted metal, (such we presume as the easily-fusible alloys,) from a hot reservoir, down to the central compartment in the interior of the hollow piston, and another of the tubes is to carry the said melted metal up again from the piston into the reservoir. Connected to the rod of the piston, in some way, there is to be a small injecting pump, for the purpose of forcing this melted metal down one tube, through the chamber in the piston, and up the other tube, making a continued circuit of the hot metal from the reservoir through the chamber of the piston, as long as the piston is in action.

"Another tube, passing through the piston rod, is designed to conduct a fluid, whether oil or water, or any

* Author of Stuart's History and Stuart's Anecdotes of the Steam Engine.

thing else, which, by heat, may be converted into an elastic vapour or gas; and this fluid being, by means of a small pump, connected to the piston rod, thrown upon the heated surface of the chamber within the piston, is immediately converted into steam, or other elastic vapour, and passing through the valves into the cylinder; there exerts its elastic force, and drives the piston as in an ordinary steam engine.

"Supposing the piston to be at the top of the cylinder and the jet of fluid to be then injected on to the surface of the heated chamber, the steam or other elastic vapour generated would immediately pass through the upper valves, which at that time are alone permitted to open, and exerting its elastic force above the piston, would instantly drive it to the lower end of the cylinder. Another jet of the fluid being now thrown upon the heated chamber, and the lower valves at this time being alone permitted to open, the steam, or other vapour generated, passes by apertures formed through the heated chamber, and instantly rushes out at the under valves into the lower part of the cylinder, and accordingly raises the piston; the steam or vapour in the upper part being drawn away through eduction apertures, and condensed by the means commonly employed for that purpose. In this way it is intended to generate the steam or other elastic vapour within the piston, and to discharge it into the cylinder, alternately on one side or the other of the piston, for the purpose of working the engine reciprocally, and with sufficient force to actuate machinery connected to the upper end of the piston rod, as in other steam engines."

High-Pressure "Safety" Engine, by J. Perkins, of Fleet Street, London. 1827.

The following diagram is illustrative of a new modification of a high-pressure steam engine, by the ingenious Mr. Jacob Perkins; the peculiarities of which will be noticed in our description. It should be understood that the figure does not represent all the details of the engine,

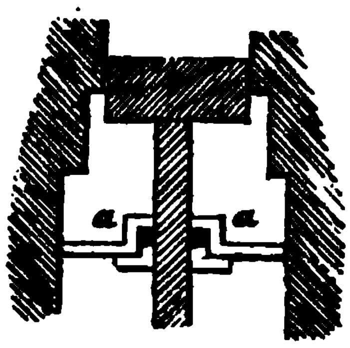
but the principal acting parts are brought together, so as to exhibit its principle and mode of operation at one view.

Reference to the engraving.—*a* is the working cylinder, supplied with steam by the valve *b*; this valve, by means of an intermediate lever *c*, is operated upon by the revolution of the cam *d*, on the main shaft *e*. *f* is the piston,

g the piston rod; *h* the connecting rod to the crank *i*; *l l l*, bearings in which the shaft turns; *m* is an eccentric, which works a valve placed in the injection tube, leading into the condenser *n*; the lower extremity of the condenser is formed into a box, having two valves, opening outwards, into the expansion vessel *o*, to which a pipe *q* is connected, leading into the hot well *p*; in this is placed a force-pump *t*, worked by a rod attached to the crank *v*, which forces the condensed water (temperature about 100°), through the pipe *u*, into the generators *w w*, fixed across the furnace, and through the opposite walls; *x* is a lower and third tier of pipes, similar to the others, but employed to allow the water from the former to expand into steam, after it has acquired sufficient power to overcome the pressure of a heavily loaded valve. From the pipe *x*, the steam passes into a large vertical chamber *y*, and from thence, at regular intervals, along the pipe *z*, into the working cylinder. The separate figure J shews one of the pipes, (the same as those at *w* and *x*,) in perspective.*

From the foregoing it will have been noticed that this engine has only what is termed a single action, the steam being admitted on one side of the piston only; and that the principle of heating water in very strong vessels, under a high state of pressure, as in Mr. Perkins's former patent, is still adhered to.

The internal diameter of the principal portion of the cylinder of the engine we saw at work in Water Lane, Fleet Street, is about eight inches, but the lower end is



enlarged, as shewn at *a a*, in the above cut, into a cylindrical chamber of nine or ten inches in diameter, and about

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* A section of this boiler, with a description of it, more in detail, is given at page 898.

six inches deep, for the reception of the piston at the end of the stroke, which takes a range of about 20 inches. The steam is admitted into the top of the cylinder, at a pressure of eight hundred pounds upon the square inch; and when the piston has descended through one eighth of the length of the cylinder, the supply is cut off, so that the remainder of the stroke is effected solely by the expansion of the steam. When the piston has reached the bottom or enlarged part of the cylinder, the steam rushes past it, through the condenser, into the expansion vessel, when the whole of it expands to atmospheric pressure. The valves at the lower part of the condenser (before mentioned), now close by their own gravity, at which instant a spray of water is injected into the condenser, by which the remaining steam is liquefied, and nearly a perfect vacuum effected. The water thus reproduced, is blown into the expansion vessel, along with the steam, at the next down stroke of the piston; the water running down into the hot well, to be returned to the generators by the action of the force pump, while the steam escapes by a lateral tube into the chimney of the furnace. The upward or return stroke of the piston is effected by the momentum given to the fly-wheel, and to prevent any resistance to the ascent of the piston, which might be caused by condensed steam above it, there is a small valve in the piston, which is opened when the latter reaches the bottom of the cylinder; therefore, whatever uncondensed steam may remain in the cylinder above the piston, has free passage from the latter to the under side, thus occasioning no obstacle to its ascent. At the termination of the upward stroke of the piston, this little valve is closed in like manner, by striking against the top of the cylinder, so that the next charge of steam introduced into the cylinder may not be diminished in its effect.

The piston employed in this engine was described as of the metallic kind, but of a very peculiar nature; *the* arrangement of its parts consisted of a series of expanding rings, but formed of a *peculiar alloy*, which Mr. *Perkins* stated he had found to require neither oil, tallow, nor any

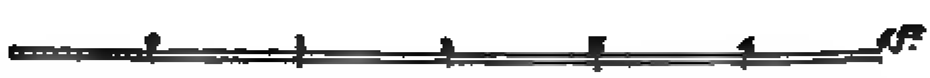
lubricating material whatever, to reduce the friction; so far from this being necessary, it was asserted, that, by the working of the engine, the rubbing surfaces of the piston and cylinder became so highly polished, as to reduce the friction considerably below that of the ordinary metallic packing, when oiled! We mention this circumstance, in order to remove the false impression which such a public statement was calculated to produce, it being, we believe, a well-authenticated fact, that the pistons made of this "peculiar alloy," did not wear well, and that it was found necessary to have recourse to oleaginous matter, to lubricate them.

One of the principal difficulties that Mr. Perkins had to contend with, in using steam at such high temperature, was the carbonising of the oil or grease; the "peculiar alloy" piston was therefore introduced, to overcome this difficulty, and we regret that the success of this contrivance was not commensurate with the expectations of the inventor.

By the novel arrangements we have described, Mr. Perkins calculated that he saved full half the fuel usually employed, and that by this mode of condensing the steam, as perfect a vacuum was effected, as in Bolton and Watt's condensing engines, with a great saving in the consumption of water, and without the necessity of, or the friction attending an air pump. Mr. Perkins has not hitherto, by any satisfactory tests, proved the power of one of these engines, and without such a datum, it is impossible to estimate the economy or advantage of them; much credit is nevertheless due to that gentleman for his varied efforts to increase the power, and thereby augment the utility of this important machine.

The preceding diagram of Mr. Perkins's new high-pressure engine was drawn with a view to explain its mode of action at one view; the proportions and relative situations of some of the parts are not strictly correct, and as the engine is one of considerable elegance and simplicity, we annex a copy of a drawing before us, which has been prepared to the scale underneath it. It represents an ex-

ternal elevation of one of the sides, supposed at right angles to the side exhibited in the foregoing diagram.



The working cylinder is represented at A H; the steam from the generators, (before described) is introduced

through the pipe C D, by a valve at E. At F is a cam, which, by the rotation of the main axis, operates through the medium of a lever G, and a rod S, upon the valve E; arrangements being made for cutting off the steam, at any point of the stroke. K is another lever, which being operated upon by another cam, opens a cock at each revolution, by which a jet of cold water is thrown into the condenser I. N is the condenser. The description of the preceding diagram, at page 711, renders further explanation of this figure unnecessary, in which the accompanying scale gives all the due proportions. The power of the engine was calculated by Mr. Perkins at 30 horses, but it was not satisfactorily proved to produce such effects.

Patent Steam-boat Engine, by Jacob Perkins, of Fleet Street, London. 1827.

This engine is a modification of the engine described in the preceding article, and adapted to steam navigation.

Fig. 1, represents an elevation of one side of the engine, in which *a* is the cylinder; *b* the steam valve; *c* the connecting rod to the piston rod *d*, and the crank *e*, on the main shaft *f*, which turns in plummer blocks *g g*; *h* shews the enlarged end of the cylinder, which is in this instance at the top of the cylinder, instead of at the bottom, as in the former.

Fig. 2, shews a continuation of the engine, with parts corresponding to those described in section; the steam valve in which being too diminutive for explanation, is described in fig. 3, (page 719) where *a* represents a lever, having its fulcrum at *g*; this lever is operated upon by the revolution of a cam on the main shaft (*f*, fig. 1) causing it to draw back the rod *b*, of the valve, at which the steam from the generators (before described) is admitted by the tube *h*, and rushes through the pipe *e*, into the working cylinder *c*. The double conical joint which connects the pipes is here represented as screwed together by the bolts *d d*, which enter the metal of the cylinder.

In this engine, Mr. Perkins purposed to use the steam

(FIG. 2.)

(FIG. 1.)

expansively, at the enormous pressure of two thousand pounds upon the square inch, and to cut it off at one sixteenth part of the stroke, the steam acting on the underside of the cylinder only, the enlargement of the cylinder

(FIG. 3.)

being at top, where the egression of the steam takes place. In the engine from which these drawings were made, the pistons were six inches in diameter, and had a twenty-inch stroke; the power was hence calculated at thirty horses power, or fifteen to each cylinder; and Mr. Perkins offered to guarantee to double that power, by using double the quantity of coals.

It is much to be regretted that this really ingenious mechanic should have uniformly undertaken to perform so much more than his predecessors or contemporaries, since he has failed to produce any of those great effects, which were so confidently held forth to the public, and without doubt anticipated by himself. Nevertheless, in the pursuit of his schemes, many excellent modifications of the minor parts of engines have been introduced by him, which entitles him to rank, in history, as one of the improvers of the steam engine.

Patent Expansion Engine, by Jacob Perkins, London. 1827.

We have now to add a description of another attempt, on the part of Mr. Perkins, to obtain the utmost effect from the expansion of steam, on the principle adopted by Woolfe and Edwards, many years back, of which some account has been given in the early part of this work.

The following account is from the pen of a correspondent in a periodical journal, from whence we extract it verbatim.

"The present improvement consists in a novel arrangement of two working cylinders, to what may be termed a single-stroke engine; these cylinders are of equal length, but the internal area of one is about eight times that of the other. The steam, at a pressure of about one hundred atmospheres (one thousand four hundred pounds to the inch,) is admitted at the bottom of the smallest cylinder, and is cut off at about one-eighth of its stroke; having forced up its piston, the steam rushes through a short bent tube, into the upper part of the larger cylinder; where it expands, and forcing down the large piston, escapes near the bottom, through lateral openings, into the condenser, and thence into the atmosphere; while the steam that remains in the condenser at atmospheric pressure, is condensed by a jet of cold water, so as to produce a vacuum therein. Both pistons act nearly at the same time, by their rods being connected to cranks above them, in suitable positions on the main axis.

"Fig. 1, represents a front elevation of the engine, and fig. 2, a side elevation; similar letters of reference indicate similar parts in each figure. *a* is the large cylinder; *b* the small cylinder; *c* safety-valve to large cylinder; *d* safety-valve and weight to small cylinder; *e e* the piston rods; *f f* connecting rods; *h* an eccentric; *i* a jointed rod to the same; *g* a crank, which works the rod *k*, of the forcing pump *m*; *n* injection cock and cold water pipe for condenser *v*; *o* steam pipe; *l* throttle-valve; *y* a pipe, leading from it into the steam valve *u*; *x* a strong spring

(FIG. 1.)

for closing valve; *q* fly-wheel; *r* weight to safety-valve *c*; *s s* plummer blocks to the main axle, in which are the cranks *t t*. *w* (fig. 2) valve-box and escape pipe for uncondensed steam.

"The steam from the pipe *o*, enters the throttle-valve *l*, and passing through the tube *y*, and the valve *u*, enters the lower end of the small cylinder *b*, where it acts upon the under side of the piston, and forces it up into the enlarged part of the cylinder; by this movement, a lateral aperture is opened in *b*, through which the steam escapes

(FIG. 2.)

along a curved tube, into the upper part of the large cylinder *a*; here it instantly expands, and forces down the large piston. Now the cranks *t t*, are set at a very acute angle with respect to one another, so that the two pistons shall perform their up strokes and their down strokes nearly together, the small piston being always a little in advance of the large one; by this arrangement, sufficient time is afforded for the admission of the steam into the small cylinder, and the discharge of it into the other. The same steam having thus exerted its force upon both

pistons, escapes at the bottom of the large cylinder into the condenser *v*, and from thence into the air, while that portion that remains in the condenser, from having expanded to atmospheric pressure, is condensed by a jet of cold water, which effects the vacuum. The induction pipe being now re-opened, the same action is renewed, and maintained by the revolution of the fly-wheel.

"The injection cock and pipe are shewn at *n*, and are worked by a cord attached to them, and passing round the cam on the main shaft. The piston rods *e e*, are furnished with guide-frames and anti-friction wheels, which, being jointed to the connecting rods *f f*, allow the latter to turn with the revolution of the cranks, and produce upon the piston rods a *parallel motion*.

"In order to determine and regulate the quantity of steam to be admitted into the cylinder, and to cut it off at the required point, Mr. Perkins has adopted a very simple contrivance: near one extremity of the main axle, there is an eccentric *h*, to which is attached the rod *i*; this rod is joined in the middle by a hollow and solid screw, by which its length is adjusted. This rod *i*, passes through a guide, and opens the steam-valve *u*, so as to admit the required quantity of steam for working the engine; a very massive and strong steel spring is employed to shut the valve, after it has been opened in the manner described.

"Between the lower end of the rod *i*, and the lever of the valve *u*, there is an intermediate bar of iron, the removal of which renders the rod *i*, too short to act upon the valve; by which means the engine may be instantly stopped at pleasure.

"As the steam is condensed, it is drawn out of the condenser *v*, by means of the forcing pump, which discharges it through the pipe *p*, into the generators, for the reproduction of vapour."

Patent Rotary Steam Engine, by Paul Steenstrup, of Basing Lane. 1828.

The above diagram exhibits a vertical section of the engine. *a* is the section of a cylinder accurately *turned*, and bolted at each end to a plate *b*, ground perfectly flat. *c* is a smaller cylinder, to which is attached a rectangular piston *d*; this piston has a metallic packing, similar to that in Mr. Galloway's engine (described page 37, vol. I, N. S.); *e* is the shaft or axis, secured by screws to the small cylinders, and turning in stuffing-boxes; *f* a slide moving in circular grooves, cut in each end-piece of the cylinder, and in a steam-tight box; *h* is a lever connected by gearing to the shaft of the engine, and serving to draw up the slide into the box, in order to allow the piston to pass. The slides are portions of a circle, of which the axis of the lever *h*, is the centre; *k* is the steam valve, and the holes *l*, the eduction passage.

The action is as follows:—The slide *f*, being down, and resting on the interior cylinder, and the piston in the position shewn in the drawing, the steam is admitted by the valve *k*, which impels the piston in the direction of the arrow; and when the piston arrives near to the eduction passage, the steam is cut off, and the piston is *carried* past the eduction passage by the impetus of a fly-wheel

on the shaft of the engine, the slide being previously raised into the box, to allow the piston to pass; when the piston has passed, the steam is re-admitted, and the operation repeated and continued.

In the case of an engine that never requires its motion to be reversed, only one slide and one steam valve become necessary; but if the power of reversing the action of the engine is required, there must be two slides, and two steam passages, as shewn in the drawing.

The leading arrangements in this engine have considerable similarity to Mr. Galloway's engine, described at page 287, and to that of the Marquis de Combis, described at page 280; the variation introduced by Mr. Steenstrup of a *curved* slider, appears to us not to possess the advantages of the rectilineal, adopted by the before-mentioned inventors, on account of the difficulty of fitting the curved parts to each other, with sufficient accuracy to prevent the waste of steam. The mode of packing the piston has the common defect of inadequately compensating for the wear at the two extreme rubbing angles. We have not heard that this engine has ever been put in operation, but we make no doubt that, with some trifling variations, it may be made to perform well.

Patent Rotary Engine, by John Evans, Jun. of Wallingford, Berks. 1828.

This engine is composed of a long cylinder *a a*, laid horizontally, and divided into two equal parts by a disk, or broad flanch *b*, in the interior; in each department is a drum *d*, composed of two concentric cylinders, cast in one piece, and a channel *e*, is formed, extending the length of the drum, and reaching from the larger to the smaller cylinder, the object of which is stated to be to *obtain greater surface.* Through these drums passes an axis *f*, with small projecting feathers, fitting into corresponding grooves in the interior cylinder of the drum, which thus comes round the axis. Attached to the periphery of the drum, by a hinge, is a flap or piston *g*, which is of

somewhat greater diameter than the channel *h*, left between the drum and the exterior cylinder *a*, and placed immediately over the cleft or channel *e*. The drums are pressed against the disk *b*, by the end plates *k*, of the same diameter as the cylinder *a*, and having their upper surface bevelled round the rim, to receive the packing, which is covered by a flat hoop, pressed down by a short cylinder *l*, by screws screwing into the flanch of *a*, so that no steam can escape between the drum and the disk *b*, or the end plates *k*. The drums must be so placed on the shaft *f*, that when the cleft *e*, of one drum is on the highest part of the shaft, that on the other drum shall be on the lowest part of the shaft. Along the upper side of the cylinder *a*, is fixed a groove, through which descends a stout shutter, on to the drum or abutment *m*, faced with brass, and having above it a packing of hemp *n*, covered with a plate of metal, pressed down by the screws *o*. The steam is admitted by the steam pipe *p*, into the steam box *q*, (of which there are two, one to each drum,) furnished with a slide valve *r*, regulated by an eccentric on the axis; *s* is the eduction pipe. The steam being admitted into one compartment, acts against the shutter *m*, and the piston *g*, and causes the drum and shaft to revolve; when, by the revolution of the drum, the piston of the other drum is carried past the aperture in the steam

box *g*, the steam is admitted to it, and shut off from the first compartment, and the revolution of the shaft is thus continued, by the admission of steam into each compartment alternately, during half a revolution. The eduction pipe may communicate either with the condenser or the atmosphere.

This invention is so similar, in its general features, to numerous rotatory engines before proposed, that we should not have given it a place in our work, had it not been to notice an error, into which we should have thought it impossible for a person describing himself as an engineer to fall. We allude to the forming of the cleft *e*, "to obtain greater surface;" by which it is understood, that the steam will act upon the surface of the cleft, as well as upon the piston *g*, whilst the steam expended will be merely that comprised in the space between the drum and the cylinder *a*.

It will be needless to observe, that the steam acting upon each side of the cleft, can have no tendency to force the piston either way; and the error is the same, as if we were to endeavour to augment the power of Bramah's press, by increasing, not the diameter of the rim, but that of the cylinder containing it.

Patent Steam Engine, by Samuel Clegg, of Liverpool. 1828.

This engine is intended to afford a compensation for the variation of the pressure of steam, used expansively, in the piston, by causing a weight to be elevated so as to cause a gradually-diminishing resistance, which weight again re-acts on the engine with a power gradually increased to its maximum. The operating vessel, in which the piston moves, consists of half a hollow ring, the transverse section of which is square, with one of the angles directed towards the centre. This semi-annular vessel is placed vertically, with its two extremities in a horizontal line; and the piston is made to traverse it in the same curve, by being attached to one end of a solid half ring, of the same form as the interior of the vessel, and nearly

of the same size, which performs the office of a piston rod, and which guides the piston in its circular course, by having its other more remote extremity united to a strong arm, which proceeds in the radial line, from a stout horizontal axle, that is placed in the centre of the circle, (of which the curvature of the semi-annular vessel forms the moiety,) at right angles to its plane. The strong radial arm passes across through the end of the solid piston connector, and there are placed in it two, three, or more flat cylindrical weights, that have perforations in their centres for its reception; the number of these weights is regulated, according to the degree of the primary pressure of the steam employed, which they, together with the solid piston connector, are intended to compensate as before-mentioned; this they perform by pressing most on the piston, when they approach close to the end of the semi-annular vessel (at which time the piston is at its other extremity), and as they arise in their circular track, and the radial arm, to which they are attached, more and more ascends from a horizontal position to one that is vertical, their pressure on the piston gradually diminishes until it entirely ceases, when the radial arm is situated as last-mentioned. To connect this engine with a fly-wheel, two other radial arms proceed from the main axle before noticed, nearly at right angles to each other, and having strong pivots fixed at right angles to them on their outer extremities; rollers are placed on these pivots, which facilitate their action on the upper internal side of a hollow vertical triangular frame; the lower angle of which is placed perpendicularly beneath the main axle, and near the inner side of the semi-annular vessel, where it is attached to a horizontal pivot, that lies parallel to the main axle; and at the inner upper side of this triangular frame, a large rounded projection is placed between the two rollers just mentioned, that performs the office of a tooth on a large scale, in which the rollers act, as well as on the internal radial sides of the triangular frame, and are again reacted on by them, as the piston apparatus performs its alternating movements, in conjunction with the revolu-

tions of the fly-wheel; to a crank on the axle of which, a connecting bar passes forwards from a pivot at the top of the triangular frame.

The engine, in the state described, is analogous to a single steam engine, and will of course not act so favourably on the fly-wheel as a double one; to obtain the advantage of which latter, a second engine, constructed in all respects similar to that described, is connected in the same manner to the same main axle, but in a reversed position, close to the side of the first, so that the movements of the pistons of the two alternate in opposite directions; the ends of the semi-annular vessels, through which the piston connectors pass, being opposite to each other, and the radial arm of the latter (by which its piston connector acts on the main axle) being at right angles to that of the radial arm of the former, when the compensating weights of one engine are rising, those of the other will descend, and when they are descending, the reverse will occur with the others.

Engines of this kind may be worked by steam from boilers of any approved construction, which must be conveyed into the ends of their semi-annular vessels, that are most remote from those through which the piston connectors pass; and from the same ends tubes must proceed to the condenser, or to the open air, whichever is most suitable to the application of the engine; these ends must of course be closed by steam-tight lids, while the opposite ends are to have stuffing-boxes, to shut up the narrow interval between the solid piston connectors and the mouths of the semi-annular vessels; the valves, and the apparatus for working them, may be of any approved construction.

We fear much that the compensating appendages introduced by Mr. Clegg, will by no means compensate for their cumbersomeness and inconvenience, especially as so little can possibly be gained beyond that of a judiciously-proportioned common engine, working expansively; the attempt is, however, praiseworthy, and the arrangements proposed, novel and ingenious.

Patent Steam and Atmospheric Engine, by Thomas Tippett, of Gwennap, Cornwall. 1828.

The above diagram is explanatory of a new modification of the steam engine by a practical engineer; it combines the principles of the high-pressure, working partly by expansion, the condensing, and the atmospheric engine.

There are two working cylinders, one termed the air cylinder, and marked 4, the other the steam cylinder, and marked 1, as those figures denote the proportionate capacities of the two; the pistons in each work together in the same direction; their rods *a* and *b*, are therefore

connected to the reciprocating beam *c c*, upon one side of the fulcrum, and at the end of the beam on the other side (not shown), the power is communicated, by means of a rod and crank, to a fly-wheel, the momentum of which gives motion to whatever machinery may be connected to it.

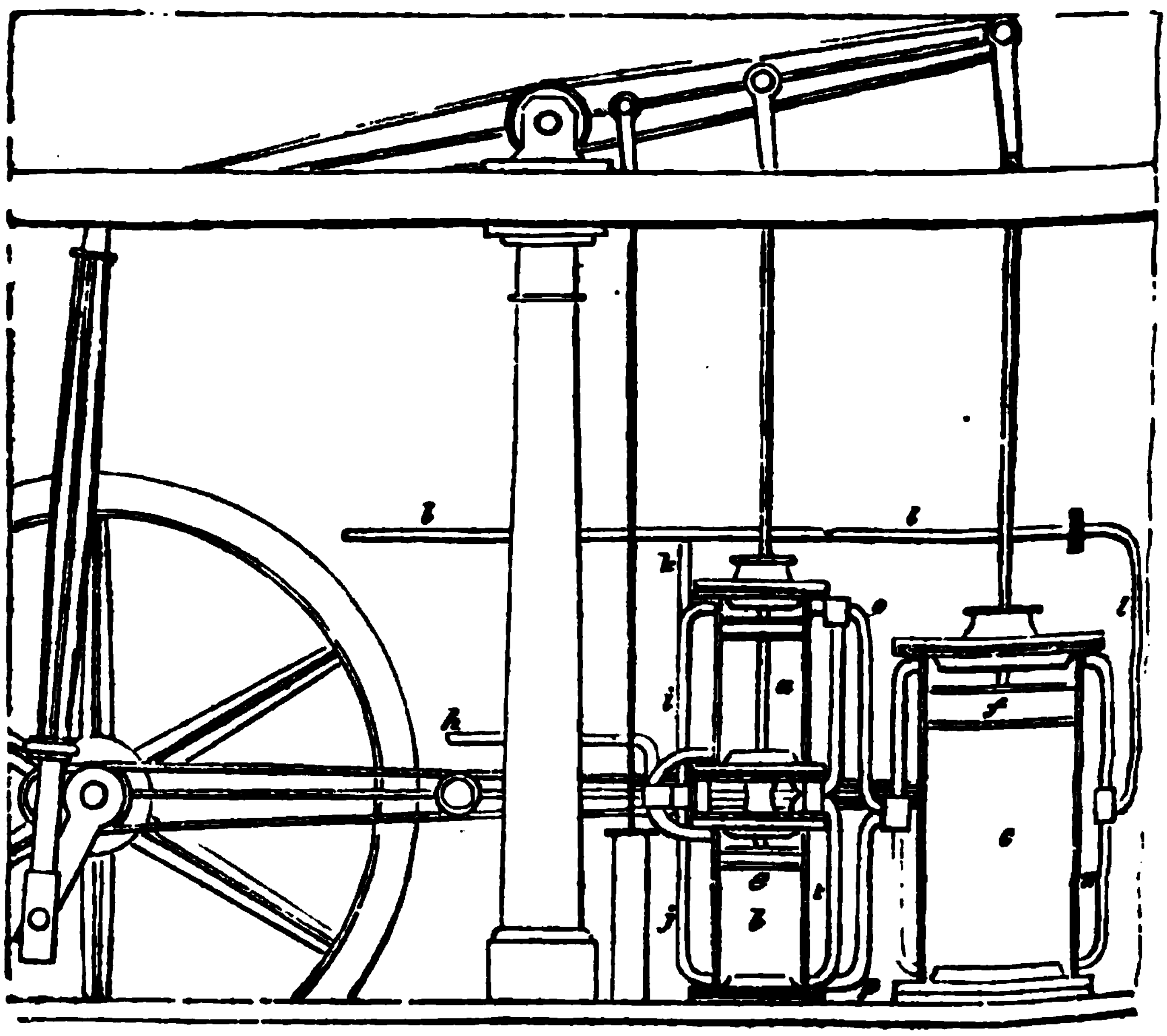
The air cylinder 4, is open at top to the atmosphere, but closed at bottom; the steam cylinder 1, is closed at both ends; *d* is a pipe communicating from the top of the steam cylinder to the bottom of the air cylinder 4, by the valve box *e*; *f* and *g* are also valve boxes, for supplying and cutting off the steam on each side of the piston in the steam cylinder 1; *h h* is an eduction pipe from both cylinders, leading to the condensers *k*; at *l* is a valve in the pipe *n*, leading from the condenser to the air-pump *o*, worked by a rod *p*, attached to the beam *c*; *q* is a rod, by which the apparatus connected with the valves are worked, but which is not introduced into the drawing, as they are of the ordinary construction; the steam from the boiler is received at *r*, for working the engine.

In setting the engine to work, steam is allowed to blow through the engine in the usual manner, to expel the air and heat the cylinders; the action is commenced by opening the communications with the lower ends of the cylinders for supplying them with steam under their pistons; the eduction valves leading to the condenser are then opened, by which means the steam is condensed, and a partial vacuum effected under both pistons. At that instant, steam at a high pressure is introduced at *f*, above the piston in cylinder 1, which forces down its piston, and as the atmosphere at the same time presses down the piston in cylinder 4, they are thus propelled together. This action leaves the atmosphere pressing upon the piston at the bottom of the cylinder 4, and cylinder 1 full of steam. To overcome these opposing forces, and reverse the action of the pistons, the communication between the upper end of cylinder 1, and the lower end of cylinder 4, is opened, while steam from the boiler is introduced at *g*, under the piston in cylinder 1; the excess of force of the fresh steam

drives the small piston upward, while the steam that was above the same, acting expansively, overcomes the pressure of the atmosphere in the cylinder 4, driving its piston also upward. Both pistons being again at the top of their respective cylinders, the steam underneath them is again condensed, and the downward stroke repeated, by the united force of high-pressure steam and that of the atmosphere, in the manner already described.

Patent Steam Engine, by John Udny, M.D. Limehouse, 1826.

This is an engine on the high-pressure plan, and consists of three cylinders, all attached, by their piston rods and parallel motion, to one end of the working beam; two of these vessels are smaller than the third, and are placed in the same vertical plane, so that one rod serves for both pistons, by passing through a stuffing-box between the



upper and the lower cylinders. These cylinders are marked *a* and *b*, and the third, or great cylinder, *c*. The two first cylinders receive the steam in succession from the boiler, and from them it enters the larger one *c*, and expands into a greater volume. *d*, *e*, and *f*, are the three pistons, with their respective rods, which being on one side of the beam, consequently rise and fall together. *h* is a pipe from the boiler, from which a branch pipe passes to each of the first action cylinders *a* and *b*, entering *a* at its bottom, and *b* at its top; so that the steam, as it is produced, will act on the under surface of the piston *d*, and on the upper face of *e*. *i* and *j*, are two pipes from the top and bottom of *a* and *b* respectively, to a pipe *k*, common to both, by which any steam that may remain in *a* or *b*, after the final expansion, is conveyed into the main tube *l*, whence it escapes into the atmosphere. *m* and *n* are two pipes from the opposite ends of the cylinder *c*, and connected to the main tube *l*.

By these arrangements, a communication is alternately opened between the spaces on each side of the piston *f*, in the cylinder *c*, and the atmosphere. *o* and *p* are pipes from the cylinders *a* and *b*, to a valve-box, from which branches the pipes *q* and *r*, which open into both ends of the expansion vessel *c*; and by them the elastic vapour which had, in the first instance, acted in *a* and *b*, is conveyed into *c* successively, on both sides of the piston. *s* and *t* are pipes leading from one end of each of the cylinders *a* and *b*, to the other respectively; and by them the dense steam is permitted to expand from the side of the pistons *d* and *e*, in which it had operated, from the boiler, to the opposite sides, so as to equalise the density and pressure in these two vessels.

Now suppose the pistons are required to ascend; then the branch of the pipe *h*, which conducts the steam from the boiler to beneath the piston *d*, and the pipe *i*, from above that piston to the air, the steam will therefore force up the piston *d*, with its full power, as it is produced (less the atmospheric pressure) as is the case in the present high-pressure engine; but at the time that this is taking place,

the steam which had, in the former stroke, forced down the piston *e*, and which after having so depressed it, at the commencement of the movement just described, existed above the piston, in a dense state, will be suffered to dilate by the pipe *t*, and pass under the piston, so as to make equal pressure on both of its surfaces, and admit of its being carried back to the top of its cylinder, without any material opposition. The concentrated steam is also allowed farther to expand through the pipes *p* and *r*, on the under surface of the piston *f*, having the internal surface of the cylinder *b*, as a fixed point of abutment, and the pipes *m* and *l* being open to the air, the piston *f* will be raised with the full expansive effort of the elastic vapour. "Thus," (says the patentee) "both the power of the steam, as it increases in quantity, and its inherent property of expansibility, are at the same time and constantly obtained." To produce the descent of the pistons, the reverse set of pipes to those named will be opened and those already mentioned shut, which it is needless to describe more at length.

The inventor estimates the relative value in power of the common high-pressure engine, and his improved one, in the following manner:

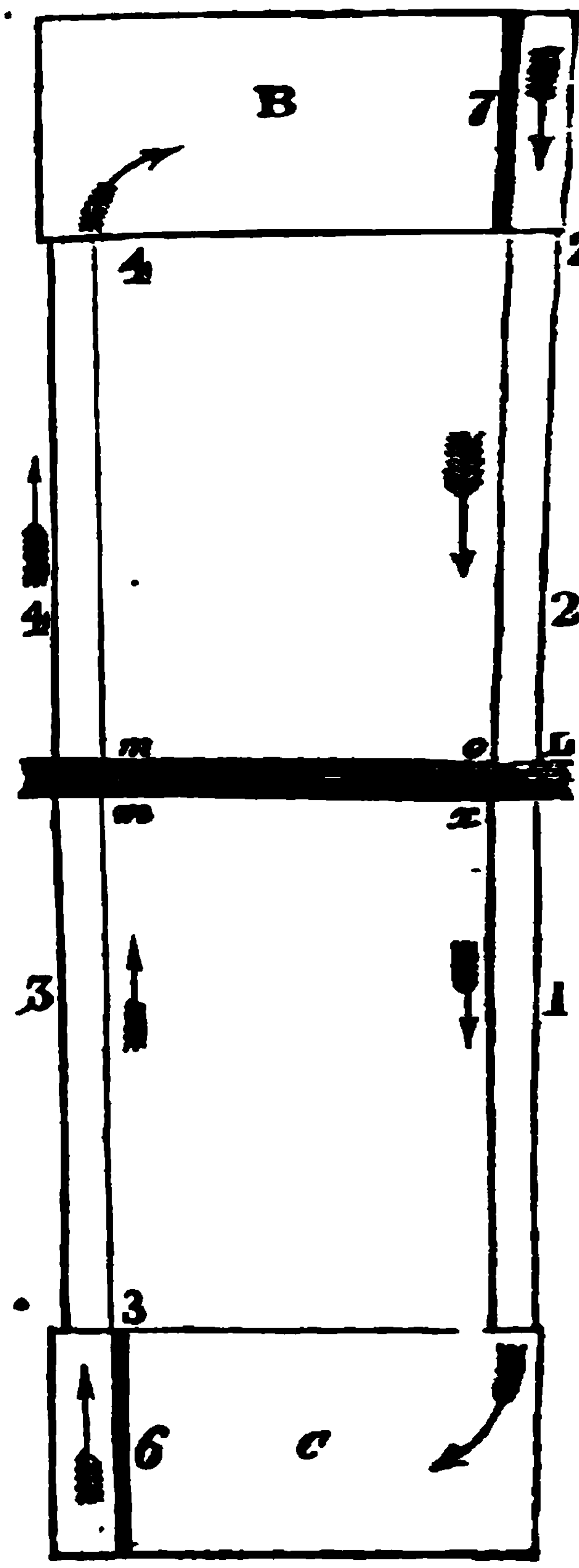
"Let it be imagined, that the piston of the ordinary engine, and the first-action pistons of the new engine, each to contain one hundred superficial inches; and that steam of forty-five pounds per inch, over the atmospheric pressure, is in each case employed; then the whole power of the old engine would be four thousand five hundred pounds, exclusive of friction; and the same would be the product of the first operation, in the improved machine. But steam of this density (sixty pounds) will dilate on four times the surface, (the stroke being the same) and still balance the atmosphere; we have therefore to add the mean between 45 and 0, on four hundred inches, or twenty-two and a half pounds per inch, which will be equal to nine thousand pounds more. If five hundred pounds be taken off for friction in the present used engine, four thousand pounds will remain; and if three thousand five

hundred pounds be allowed from this one for the same reason, no less than ten thousand pounds will be left; and large and ample as this deduction for friction, &c. is, if even two thousand pounds more be subtracted, the power of this machine would be double that of the present one, from the same fuel;" and he further adds, that "in the condensing modification of the engine, the result will be still greater, and such application of the principle will be easily conceived."

Mr. Udny's arrangement is both novel and curious, but we are not convinced by his argument that any gain in effect results therefrom. He claims for himself the having obtained, "both the power of the steam, as it increases in quantity, and its inherent property of expansibility at the same time," whereas those powers are already obtained in the common high-pressure engines, working expansively, which they generally do to a greater or less extent; and from the superior simplicity of the latter, there is much less friction, and the cost of construction much less.

The same gentleman included under his patent a description of a rotary engine, which was intended to operate by the gravity of a fluid, or metal that is fusible at the boiling point of water, acting on the circumference of a wheel, and which is propelled from one vessel at or near the bottom of the said wheel, by the power of steam, into another vessel at the top, in the following manner:—

"In the annexed figure is an axle or gudgeon, which must be fixed; at one end it is hollow, up to the inside nave, where the wheel revolves, which hollow is divided into two. The mouth of one of those openings points upwards, and the other downwards; or two pipes run into this axle as far as *o* and *x*; the first being from the condenser, or atmosphere, and the second, *x*, from the boiler. In another part of this axle, at *m*, a perforation runs through the axle. On this axle, or gudgeon, is strung a double wheel, which rotates freely on it; one of the naves of the said wheel being over the mouth of the holes *o* and *x*, and the other revolving at *m*. This double wheel has



cylinders (any number) placed between its side at the circumference, every two being opposite; the ends of these cylinders being at the internal part of the rim of each wheel, as B and C. In them may be pistons, as 1 and 2. Pipes, which may be the arms or spokes of the wheel, are to run from one cylinder to the other, at each end of said cylinders; and thus each radius will be alternately the steam pipe and the eduction one, as it comes to the pipe over the axle marked *o*, to the condenser under the hole marked *x*, the mouth of the pipe to the boiler. No valves will be necessary, but a cock, to shut off the steam from the axle when wished.

"Now, suppose C to have come to the bottom full of fluid, the gravity of which will have turned the wheel into the now imagined position. The pipe 1, will then present its opening to the mouth of the pipe in the axle *x*, leading from the boiler; while the mouth of the pipe 2, will be in contact with the mouth of the pipe *o*, in the axle, leading to the condenser. A vacuum will therefore exist on one side of the piston 7, in B, and the steam will pour into C, in the direction of the arrow behind its piston 6, forcing it along, and propelling the fluid on the other side of it, up the pipes 3 and 4, into B. When B comes to the bottom, the reverse will take place; 2 will be opposite the mouth of the steam pipe *x*, and 1, the eduction one, *o*. The steam will flow into B, and the fluid be propelled from it up to C, and so on."

Patent Steam Engine, without Pistons, by R Williams, of Tabernacle Walk, London. 1829.

The object of the patentee is to obviate the expensive wear and attendant friction of metallic or packed pistons, moving in cylinders; and this he effects by having his steam cylinders open at one end, and inverted in a vessel of dense fluid, which will require a much greater heat to convert it into vapour than water; so that steam being admitted successively into the cylinders, three in number, which are attached by rods to a three-throw crank, they are forced up in succession, and give motion to a shaft, which may be attached, in the usual way, to any machinery required to be put in motion.

The drawings attached to the specification of this patent represent, situated over a furnace, an oblong boiler, about half filled with water, the remainder being occupied with steam. Above the boiler is bolted thereto, by means of projecting flanges, the dense fluid vessel, of the same area, but of greater depth than the boiler. To the bottom of the upper vessel, (which is about two-thirds filled with oil) are fixed, in a vertical position, three steam reservoirs, of a cylindrical form, with hemispherical tops, and the steam is supplied to them from the boiler underneath, through apertures regulated by sliding-valves. Over each of these reservoirs are placed three inverted vessels (or substitutes for pistons), which are of considerably greater capacity, their upper extremities, which are hemispherical, being attached to the rods of the three-throw crank before-mentioned. In the upper part of these vessels are valves for the escape of the steam, which open when their stems strike against the top of the oil-vessel, and the steam thus discharged over the surface is carried off by a lateral pipe into a condenser.

Supposing one of the three vessels (which are raised and depressed successively by the rotation of a crank) to be submerged in the oil, and at its lowest point of descent,

it thereby opens a conical valve in the upper part of the steam reservoir, which it encloses, or "caps over;" the steam passing then out of the reservoir into the external vessel, raises the latter with a force equal to the difference between the specific gravity of the cylinder full of steam, and the oil (or other dense fluid) in which it is immersed, and through the instrumentality of the three-throw crank, each of the cylinders is brought successively to operate in the same manner.

We suspect the patentee has overrated the imperfections of steam engines of the usual construction, as well as the power to be derived from his own, which, to produce an effect equal to an engine of the common construction, of forty or fifty horses power, would require to be made of a very inconvenient magnitude.*

Rotary Steam Engine, by Thomas Smith, Derby. 1829

This engine, which displays much ingenuity, differs from all other rotary engines in its having no fixed fulcrum for the steam to act against; but it has two vanes or pistons turning upon axes, whose centres of motion are coincident with each other, and with the axis of the cylinder into which they fit steam-tight. The axes of these two vanes or pistons are connected by a train of eccentric toothed wheels, which cause them to revolve with different velocities, so that the pressure of steam between the vanes can take place with their moving, and having got to that position when the vane which was moving quickest, passes the eduction pipe, and the one which was moving slowest, passes the supply pipe, situated about one-sixth of the circumference of the cylinder from the eduction pipe, the position of the wheel work is so far changed, that the first vane then moves slowly, and the second quickly; and thus a continuous rotary motion is produced, which may be applied to give motion to machinery, or in *pumping*

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* A drawing of this engine is given in the Register of Arts, &c.

water, if motion be communicated to the apparatus, and the supply pipe made to communicate with the water to be raised.

Patent Steam Engine, by Elijah Galloway, of London. 1829.

The improvements here contemplated consist of arrangements, by which a continuous rotary motion is obtained from an alternating circular motion of a piston or flap, vibrating within a hollow cylinder, on an axis coincident with the axis of the cylinder. The piston in this instance is a rectangular flap, whose length is equal to the interior length, and its breadth equal to the radius of the cylinder. Three sides of the piston are made to fit the interior of the cylinder steam-tight, by metallic or other packing, and the fourth side is attached to an axis, with which it vibrates, making about three fourths of a revolution at each vibration. It is scarcely necessary to remark here that the steam is admitted on the opposite sides of the piston, alternately through the medium of a two-way cock, or shifting valve, acted upon by the motion of the apparatus. The force of the steam thus exerted upon the piston is transmitted to a fly-wheel, and thence to any required purpose, in the following manner:—To one end of the piston axis, which is passed through the end of the cylinder, is fixed a crank, which, by acting in a longitudinal slit, in the middle of a lever moving on a fixed pivot at one end, alternately elevates and depresses the other, and thus through the medium of a connecting rod, communicates motion to the fly-wheel.

Although this engine is the invention of the author of the "History," or first part of this work, we have not had an opportunity of seeing it in action; we are however credibly informed that its performance is very satisfactory:—The foregoing brief description is given after having perused the specification of the patent at the Enrolment Office.

Patent Steam Engine, by Moses Poole. London, 1829.

This invention is stated to have been communicated to the patentee by a foreigner residing abroad, and this circumstance will account for its want of novelty. Notwithstanding which, it is, we are informed, patronised and adopted, by Mr. Gurney and his colleagues, in the construction of their steam coaches; that being the case, it may be presumed to possess some advantages; we accordingly give it insertion here, without, however, entertaining a favourable opinion of its merits.

The invention consists of a steam boiler, composed of a series of straight tubes, placed horizontally, some under, others over, and some on each side of the fire. The first tube is joined to the second at one end, and the second is joined to the third at the other, so that the whole boiler consists, in effect, of one continuous tube. Through this the water is driven by a force-pump, and when sufficiently heated, it is admitted into a vessel called a separator, and thence conveyed to the working cylinders. From the cylinders, the steam is conveyed, still in a highly-elastic state, to a reservoir, from which it escapes by four very small apertures up the chimney, carrying with it the air in the chimney, and by that means creates a current, which may be increased or diminished at pleasure, by an alteration of the apertures through which the steam escapes; which apertures must never be so large as to allow the steam to escape from the reservoir so fast as to diminish its elasticity; a circumstance which would cause an irregularity in the passage of the steam, and consequently of the draught of air through the chimney

When this apparatus is applied to a locomotive carriage (the specification states), it is necessary to supply water to the boiler before the carriage starts, as well as during occasional stoppages, which the patentee purposes to effect by hand, or by lifting the wheels off the ground, and then working the pump by the engine, as the wheels may then turn without propelling the carriage.

The carriage is lifted by a lever extending from the axletree, or a fixed point near it, and reaching a few inches farther than the circumference of the wheel; and when this lever is brought directly under the wheel, by winding a chain from it on a drum, or drawing it by a piston in a small steam cylinder, the wheel is at liberty to turn freely. The patentee purposes to use the same contrivance as a drag to impede the progress of a carriage when descending hills.

Hydraulic Steam Engine, by John Catlin, Cincinnati, Ohio, U. S. 1829.

This is, in fact, an engine working entirely upon the principle of Savery's engine. It is said to be "peculiarly applicable to mills already erected on streams which fail during part of the year, as the expense of constructing it is much less than of an ordinary steam engine of equal power."

Savery's engine, as usually described, was to operate both as a sucking and forcing-pump. The water being first raised by the pressure of the atmosphere into a chamber, in which a vacuum has been produced by the condensation of steam acting upon the surface of the water. In the arrangement now proposed, the forcing operation is the only one employed. Two or more cylinders are made of wood, and are placed in the reservoir from which the water is to be raised, so that it will flow into them without the aid of a vacuum. Wood is chosen, because it is a bad conductor of heat. Floats of wood are to rise and fall within these cylinders, and are to operate as pistons; they are to be "closely fitted, without touching the sides, to separate the steam from the surface of the water, and thereby prevents its condensation." After these cylinders have been filled with water, through a valve in their bottoms, steam is to be admitted into them above the float, and is, by its elasticity, to force the water to the required height. The patentee says;—

"The improvement for which I claim an exclusive privilege is, the use of wood, or other non-conducting mate-

rials, to construct the vessels, or cylinders, and floats, above described, and to line with the same material, iron, or other metallic vessels or cylinders, for the alternate reception and discharge of steam and water."

It will be no easy task to *fit the floats closely without touching the sides*, so as to prevent the water from passing above them, when under the pressure of a high column in the rising shafts. The slowness with which wood conducts heat, would be an advantage in this plan, but the impossibility of making it keep its form and dimensions, under the action of water and steam, will render some unmentioned provision necessary, or it must be fatal to the whole scheme. Steam of two atmospheres will be necessary to raise water to the height of thirty feet, on this plan.

In situations where fuel is cheap, an economical engine for raising water from a tail-race into a dam, might be advantageously employed during seasons of drought; but it rarely happens that there is a supply in the tail-race, when there is a deficiency in the dam; it is, therefore, in but few places that such an apparatus would be of any avail; it has, however, been effected in some places, but the very nature of things forbids its frequent adoption.*

Patent Steam Engine, by Thomas Banks, Patricroft, Lancashire. 1829.

Mr. Banks describes two improvements in connexion with the steam engine; the first applicable to the supply of oil, or other lubricating material, to the piston, and the second, to the supply of steam to the cylinder. The oil, or melted tallow, which the patentee prefers, is conveyed through the piston rod, made hollow for the purpose, to a ring situated half-way between the top and bottom plates of the piston. This ring being made open towards the cylinder, which it approaches very near to, affords an abundant and uniform supply. The tallow is introduced into the hollow piston rod, by means of a vessel precisely

* Journal of the Franklin Institute

like a tobacco-pipe, with its shank stuck into its side, and its mouth turned upwards, for the reception of the tallow. The second part of the invention consists of a revolving pipe, for the passage of the steam alternately above and below the piston, and from the cylinder to the condenser, or to escape, when no condenser is used. The revolving pipe extends the length of the cylinder, and has, at each end, two apertures on opposite sides, and a fixed partition twisted into half a spiral, so as to form a communication between the upper opening on one side, and the lower opening on the other. On the upper end of the revolving pipe is placed a collar, through which an opening communicates on one side with the boiler, and on the other with the cylinder; and the lower end turns in a similar collar, with communications from the cylinder on one side, and the condenser on the other. Now it is evident, from the position of the spiral partition, that each opening at the top is connected with the opposite opening at the bottom; and hence, as the pipe revolves, the communications are alternately opened between the boiler and one side of the piston, and the condenser and the other. This is an application of the principle of the two-way cock, which possesses considerable ingenuity, and may be found, in some cases, very serviceable.

Patent Improvements in Steam Engines, by W. Church, of Birmingham. 1829.

The improvements here contemplated, are applicable to the supply of fuel to the fire, to the boiler, the method of opening and closing the steam passages, the whole arrangement of the different parts of the engine, and its application to propelling vessels, through the medium of propelling wheels of a peculiar description.

The fire-feeding apparatus consists of a coal-hopper, having at its lower extremity a small revolving roller, with four vanes, which transfers the coals in small quantities from the hopper to a plate situated within the furnace doors, and somewhat higher than the surface of the

fire. From this plate the coals are driven forwards, and scattered over the fire by a projecting rake, which fills the aperture through which it passes, having on its upper surface a flat plate extending under the hopper, when the rake is driven forward, and thus communication with the air is prevented. The rake is actuated by the engine, through the medium of a series of levers.

The boiler proposed by Mr. Church is of the tubular kind, in which the fire is made to play round the tubes, with a peculiar arrangement of connecting pipes proceeding from the upper part of one tube to nearly the lower part of another, according to its elevation; by this, the quantity of water and steam in each is regulated.

Two plans of opening and shutting the steam passages are described. In the first place, the steam is admitted into the cylinder, and permitted to escape from it through holes in its top and bottom plates, by means of additional plates with smaller holes, which are alternately brought opposite the holes communicating with the cylinder, the boiler, and the condenser. The cylinder is furnished with a jacket or steam chamber, extending above and below, as well as round it. The exterior top and bottom plates are made, by means of a crank-motion, to oscillate, and thus the communications between the cylinder and boiler, and cylinder and condenser, are alternately opened and closed. A plan similar to this, was introduced eight or ten years ago, by Mr. Jacob Perkins, who caused his communication-plates to rotate, instead of vibrate (see page 245, valve *e*). A second plan of opening and shutting the steam passages, is described to consist of two flap-valves, placed in a pipe, which communicates with the boiler at one end, and the condenser at the other. A communication is opened from the top of the cylinder and the space between the valves, which are joined by a connecting rod, so that the motion which opens one shuts the other, and the upper part of the cylinder is constantly in communication either with the boiler or condenser. A similar set of valves and pipes effect the same thing between the lower part of the cylinder and these vessels.

Steam and Gas Engine, by William Willmot Hall, of Baltimore, America.

This engine, which is applicable to all the purposes for which steam engines have been usually employed, is actuated by a mixture of steam and gas, in the following manner. Into a steam boiler, of any convenient form, is introduced a pump, called, by the patentee, a gas pump, in capacity about two-thirds of the working cylinder of the engine. This gas-pump is made on the double-action principle, and receives its supply of gas, or heated elastic fluid, from the chimney flue, which is made to pass through the boiler, by a pipe communicating with the top, and another with the bottom of the pump; both these supply-pipes are furnished with valves, opening towards the pump, which is likewise furnished with two outlet pipes, communicating, the one from its top and the other from its bottom, into the upper or steam parts of the boiler. These pipes are likewise furnished with valves, but opening in a contrary direction to the others, or from the pump towards the boiler.

The packing of this pump-piston must be metallic, and the valves, or the communication between the chimney and pump, must be lined with platina, to prevent their being injured by heat.

The piston rod of the gas-pump passes through a stuffing-box at the top of the boiler, and is connected with and actuated by the working cylinder of the engine. After the steam is up, and the engine thereby put in motion, the chimney is closed by a damper, situated just above the insertion of the supply-pipes, when the hot elastic fluids issuing from the fire, are pumped into the upper part of the boiler, where they mingle with the steam, and are conveyed in the usual way to the working cylinder.

We cannot ascertain, either from the title or the specification of this patent, whether the patentee intends, by his invention, to improve the effect of steam in actuating

machinery, or to destroy the disagreeable effluvia arising from the flues of engines, by mixing it with the steam in the boiler; we should imagine, however, that he intends the latter, as he gives, in the same specification, a description of a method of supplying the furnace uniformly with coals. And this he effects by placing over the furnace a hopper, with a moveable piston-shaped bottom, perforated with a number of circular holes, about six inches diameter. This hopper bottom is furnished with a vertical rod, by which it is suddenly lifted and let fall by every stroke of the engine, thus agitating the fuel in the hopper, and producing a regular supply through the circular holes in the bottom plate.

Broderip's Improvements in Steam Engines, patented by Joseph D'Arcy, of Leicester Square. 1829.

(As Legatee to the Inventor.)

By this invention it was proposed to connect the upper end of the piston rod immediately to the crank by which rotary motion is produced, without the intervention of guide rods, or parallel motion; neither does he require the cylinder to oscillate; but he makes the piston rod to accommodate itself to the different positions of the crank by vibrating, and for that purpose it is attached to the piston by a hinge joint. And the stuffing-box through which it passes is made to slide in a dove-tail shaped groove, backwards and forwards, across the top of the cylinder; while that part of the box, through which the piston rod passes, has a small oscillating motion on steam-tight joints, that it may retain the position of the piston rod.

Instead of this sliding stuffing-box apparatus, the patentee purposes, under certain circumstances, to surround the vibrating piston rod by a cylinder which is attached steam-tight to the piston, and made sufficiently wide for the piston to vibrate within it. In this case, it is evident, that the inclosing cylinder, and not the piston rod, must work steam-tight through the stuffing-box.

It is not very clear what advantage the patentee had in

view by these arrangements, but it is probable that he has overrated the imperfections of the parallel motion and the sling-connecting rods and guides usually employed; as it is perfectly evident, that either of the plans which he has patented will add to the difficulty and expense of manufacture, and also to the waste of power, by an increase of the rubbing surfaces; whether they be in the form of a sliding stuffing-box, or the enlarged cylinder, working through a stuffing-box of the usual construction. Besides, in the latter plan, the area of the upper side of the piston is so much diminished by the piston rod case, that the difference between the force of the steam exerted on the upper and under sides of the piston, will cause an irregularity in the operation.

In addition to these inventions, the patentee describes a method of transmitting motion from one part of machinery to another, which consists of similar cranks, connected together by rods either straight or branched; and this is said to be very useful on board of steam vessels; but it is really a contrivance possessing so little originality and importance, that workmen have long been accustomed to design such plans, whenever they required to transmit motion to different parts of a factory, or of a machine, without ever imagining that they had invented any thing worth protecting by his Majesty's letters-patent, or even communicating to their fellow-workmen.

Patent Steam Engine, by E. and J. Dakeyne, of Darby Dale, Derbyshire. 1830.

This invention consists of a hollow spherical vessel, having within it a moveable globe; of a diameter considerably smaller than the interior diameter of the hollow sphere.

From the upper part of the interior ball proceeds a tapering rod, which passes through a large hole in the hollow sphere, and turns with a conical motion, giving motion to a horizontal crank and a train of wheels. To

the equator of the ball, regarding the tapering rod as its pole, is attached a flat ring, which extends to and fits steam-tight within the hollow sphere. On one side of this ring a notch is made, to admit two communications, the one for the ingress and the other for the egress of the steam or other fluid by which the machine is to be put in motion.

Now, suppose the ring to be raised on the side next to the passages, the steam water or other actuating fluid can enter, but cannot pass round to the egress passages, without raising the ring on the opposite side; and it cannot, from its connexion with the crank, be raised on the opposite side, without causing the tapering bar to describe a conical motion, which is converted into a circular motion, through the instrumentality of the crank

Patent Steam Engine, by W. Grisenthwaite, Esq. of Nottingham, 1830.

The certain improvements here contemplated are of the most extraordinary kind we have ever met with, in a specification of a patented invention; for it is merely said to be the application of iron weights with the mercury or other fluid metallic substance in the rotary engine patented by Mr. James Watt, in 1769. The iron weights are to be furnished with anti-friction rollers, to facilitate their motion in the channel of the wheel. The present patentee does not describe the engine to which he is to apply his improvements; and as Mr. Watt invented and patented several, and notices them in the following vague terms, it is difficult to comprehend the precise nature of the present invention. Mr. Watt says, "When motions round an axis are required, I make the steam vessels in form of hollow rings or circular channels, with proper inlets and outlets for the steam mounted on horizontal axes, like the wheels of a water mill. Within them are placed a number of valves, that suffer any body to go round the channel in one direction only. In these steam vessels are placed weights, so fitted to them as entirely to fill up a part

or portion of their channels, yet rendered capable of moving freely in them, by the means hereinafter mentioned or specified. When the steam is admitted into these engines between these weights and valves, it acts equally on both, so as to raise the weight to one side of the wheel, and by the re-action on the valves, successively to give a circular motion to the wheel, the valves opening in the direction in which the weights are pressed, but not on the contrary. As the steam vessel moves round, it is supplied with steam from the boiler, and that which has performed its office, may either be discharged by means of condensers, or into the open air."

In addition to the improvements on Mr. Watt's rotary engine, Mr. Grisenthwaite claims the application of mercury to the rubbing parts of machinery generally, instead of oil or other lubricating material.

Patent Steam Engine, by Benjamin Reeves, Philadelphia 1830.

The claim of the patentee, (which only extends to the United States,) exhibits pretty fully the general object of the patent; it is in the following words: "What I claim as new, as my own invention, is a mode or modes, by which lubricating substances may be applied to the interior surface of cylinders or other vessels, in which moving pistons operate, in steam, hydraulic, or other engines, in such a manner as to prevent their escape to the cavity of the cylinder, or other vessel, other than by contact with their surfaces."

Several modes, it is said, may be adopted for the purpose indicated, and one of which is described in the specification; it consists in leaving a cavity around the piston, in the centre of the packing, which cavity is to receive the lubricating substance. A ring of iron, or other metal, is made of the size of the interior of the cylinder; a groove is formed on the outer edge of this ring, and when the piston is packed, the ring is to be inserted in the middle of it. A tube, with a funnel and cock attached to it, passes

through the side of the cylinder, and whenever the piston is brought to rest with the cavity opposite to the tube, the lubricating matter may be admitted. There is a second tube and cock on the opposite side of the cylinder, to allow of the escape of air or vapour, which might obstruct the influx of the lubricating fluid. "The lubricator may be supplied, when the engine is in operation, by means of cams, or other contrivance."

Patent Rotary Steam Engine, by John Street, Esq., of Clifton, Gloucestershire. 1830.

Mr. Street purposes to place upon the same axis two cylinders, so arranged with respect to the steam passages, that the communication beween the boiler and the cylinder is opened to the one, while it is closed to the other; and thus the action on the axis is kept up by one of the cylinders, during the time that a piston or fan, which is attached to the axis, passes a steam stop, which is made to fold back in a recess in the upper part of the cylinder.

The admission of the steam into the cylinder is by means of a hollow axis, which turns within them, and through the medium of which the power is to be communicated to any required purpose. A steam pipe from the boiler terminates in a box through which the hollow axis passes, being rendered steam-tight, by packing on each side. Several longitudinal openings are made into that part of the axis which is within the box. The area of these openings being made equal to the interior area of the steam pipe. By this means the hollow axis becomes charged with steam, which passes from hence into the cylinders, by two pipes in connexion with two other steam boxes, which fit steam-tight where there are openings on opposite sides of the axis, so that the communication is always open to one of the cylinders, while it is shut off from the other. The cylinders are both fixed on firm stands, and there is placed within each, a rectangular piston or fan, which is to be fixed on one edge to the axis, and packed

so as to work steam-tight, against the periphery and ends of the cylinder. As a steam-stop, a rectangular piece is jointed to the upper part of the cylinder, and turns back into a recess, while the piston passes it. One of the pivots on which the steam-stop turns, passes through a stuffing-box, and has attached to it a lever, with a weight to constitute a counterpoise to the steam-stop; or the recess into which the steam-stop turns is made large enough to admit of a counterpoise being applied within the steam-tight cylinder. The steam-stop is made to fall into the position of its action, either by its own gravity, or else it is actuated by exterior cams or eccentrics.

Mr. Street proposes another method of admitting the steam into the cylinders, which he states may be sometimes employed with advantage; it consists of two valves attached to the extremities of a lever turning upon a fulcrum at its middle, by which one of the valves is opened upwards and the other downwards at the same time. These valves, with their seats, are included in an enlarged part of the steam passage, and they are actuated by a lever, the extremity of which rests upon the periphery of a wheel, and by dropping into a notch on one side of the wheel, the valves are opened.

Improvements in Steam Engines, by William Tutin Haycraft, M.D. Greenwich. 1830.

It has been found, as stated by Dr. Haycraft, that steam surcharged with caloric, or such as has been augmented in temperature, after it has assumed the gaseous state, is exceedingly difficult to keep from passing the piston in the working cylinder, and from injuring the packing, if made of hemp or similar material, as well as from carbonising the tallow or oil used for lubricating the cylinder and piston.

The patentee having ascertained, experimentally, that the elasticity and power of steam can, by the application of heat after the steam is generated, be greatly augmented,

with a comparatively small consumption of fuel, set about inventing an engine to be worked with surcharged steam, without its being liable to the objections above alluded to. The plan by which he purposes to preserve the piston packing and oil from being carbonised, and at the same time to prevent the high-pressure steam from passing the piston on which it presses, is to keep water on the under side of the piston, while the steam only acts on the upper side. This he effects by placing his boiler in a position higher than the working cylinder, and making a communication from the bottom of the boiler to the lower end of the cylinder, and from the top of the boiler to the upper end of the cylinder. The piston rod, which passes through the bottom of the cylinder, is made so thick, that the square of its diameter shall be just half the square of the diameter of the cylinder, or that the area of a section of the piston rod shall be half the area of the lower side of the piston. This being the case, it is evident that the water can only press upon half the area of the piston, the thick piston rod occupying the other half, while the steam acts upon the whole area of the upper sides; hence, when the steam passage from the top of the boiler and the upper end of the cylinder is open, the piston will be forced down with a power of *two*, while it is resisted, by the water-passage from the bottom of the boiler to the lower end of the cylinder, being open by the power of *one*; so that it will descend with a power of one, and when it reaches the bottom, the steam communication is stopped off, while the steam, now in the cylinder, is allowed to escape through an eduction valve; when the piston will ascend by the pressure of the water below it, with a power of one, or the same with which it descended. When the piston reaches the top of the cylinder, the steam passage is again opened, and the eduction cock closed, when it will be forced down as before; and thus a constant and uniform action is obtained by the action of water on one side of the piston, and the action of steam on the other. When it is inconvenient to place the boiler higher than the working cylinder, a water-cylinder is introduced,

which is made to communicate with the boiler, and thus answer the same purpose as the elevated boiler.

The contrivance is so ingenious, that we cannot but regret to notice what may, in some measure, be deemed a defect; but it will readily be perceived, that an increase of friction will result from the enlargement of the piston rod. The arrangement of the different parts of this engine will be at once comprehended, by inspecting the accompanying engraving, where *a a* represents the working cylinder, with its piston *b*, and a large piston rod *c*, pass-

ing through its stuffing *b g g*. *d* is the boiler, with a communication *e e*, for the water to pass freely between it and the lower end of the cylinder. *f f* is a steam communication between the boiler and the upper end of the cylinder, represented as broken off. In connexion with this steam passage, is a two-way cock, of the usual construction, for permitting the steam to escape, after it has forced the piston to the bottom of the cylinder. Sometimes the upper or steam end of the cylinder is surrounded by a portion of the flue, to continue or increase the elastic force of the steam; but when this plan is adopted, the cylinder must be protected from injury by a coating of fire-brick, or other non-conducting material.

Several ingenious modifications of this principle of working alternately with steam and water are described in the specification of the patent, which are deserving of the attention of engineers; but from the drawings given of them, (one of which is inserted in the Register of Arts, &c. for January, 1831,) it would appear, that considerable obstruction to the motion of the piston would arise from the smallness of the water passages, and power would necessarily be wasted in causing water to pass through pipes with great velocity. There will, however, be but little difficulty in adjusting the magnitude of the various parts of the apparatus, to avoid all imperfections of this description. It will also be necessary to use either distilled or very carefully filtered water, to prevent the injury to the piston and cylinder, which would be caused by the introduction of sand, or other gritty matter.

STEAM ENGINE FURNACES.

About fifty years ago, when, from the great improvements introduced by Watt and his contemporaries, steam engines became very numerous, many scientific and practical men directed their attention to the discovery of some means by which the large quantities of dense black smoke issuing from the chimneys of the furnaces (so prejudicial to the comfort, if not to the health, of the neighbouring inhabitants,) might be prevented. Numerous were the plans tried to consume the smoke, and although some were partially successful, they were found generally either inconvenient, or occasioning a greater consumption of fuel, so as to lead to no advantageous result to the proprietors, however the public might be benefited by their adoption. These circumstances led to the abandonment of most of the plans, except in those instances wherein the proprietors were compelled to their adoption and continuation by indictments for public nuisances.

With the laudable object in view of reducing the great and growing evil of dense smoke in populous places, the Society for the Encouragement of Arts, &c. have, for nearly fifty years past, offered a reward for the best method of consuming smoke in steam engines and other furnaces. The constant notification of this reward has probably tended to keep the subject alive in the minds of inventors, but it does not appear to have been productive of many plans being submitted to the Society, that could be deemed of any great practical value. (The only one which we are aware of, that has any claim to this character, was the invention of Mr. Robert Chapman, in 1823, which we shall describe in its place.) The intrinsic value of the reward was most likely deemed by inventors as a very trifling compensation for a discovery which was calculated to "make their fortunes," and induced them to prefer in-

curring the cost of patents, and thus take a great deal of money out of their pockets, instead of putting a little in; viewing their inventions, of course, as the *ne plus ultra* of perfection, and confidently anticipating golden harvests as their results.

It has been usual to consider Mr. Watt as the earliest inventor of a furnace for the combustion of its own smoke, and perhaps, as respects its application to steam-engine furnaces, the idea is correct. In France, apparatus for the purpose was used in many manufactories, in the seventeenth century. * In the volume of the Academy of Sciences for 1699, some experiments, by M. de la Hire, are given, which have reference to an invention, made many years previous, by M. Delasme, a French engineer. The latter, we are told, exhibited his furnace for consuming its own smoke at the fair of St. Germain, in the year 1685.*

The fire-place of M. Delasme consisted of a long tube, bended into the form of a syphon inverted, the longest leg of which formed the chimney, and the shortest the furnace. The fuel was deposited on a grating near the top of the shortest leg, being supplied from above. Soon after the ignition of the fuel, the heat was communicated to the longest leg or chimney, and by that means a current of air was caused to pass downward, through the fuel and under the grate, where the smoke was consumed.

Delasme's apparatus was described in Dr. Boerhaave's Treatise on Chemistry, and likewise in Annales de Chimie, for 1809; in a report made by M. Guyton Morveau and De Proney, on a method employed at the mint, in Paris, by M. Gengembre, to consume the smoke of a steam engine furnace; and as some of the observations of those gentlemen seem to afford a very clear view of the theoretical part of the subject, we shall here transcribe them from an English translation.

It is well known that black smoke is formed of the volatilised parts of the fuel, which are suspended in the

* See Transactions of the Royal Society, vol. xvi, page 78.

transparent gases given out in the process of combustion. These volatilised parts are, as it were, lost to the fire, partly because the mass of air which yielded the oxygen was not in a proper proportion to the quantity of the fuel, and partly because the fuel was not sufficiently heated to decompose the air with which it was in contact. The recent progress which the theory and practice of the arts which depend upon chemistry have made in France, have furnished, for some years past, several important occasions of finding out the best method of fulfilling the conditions necessary for a complete combustion, free from any inconveniences; the principal of which are:—

First, such a disposition of the fire-place, that a current of air may be established, flowing through the door, or some opening into the pipe or chimney, by which the gases, set free by the combustion, are allowed to escape.

Second, the flowing upon the fuel of a mass of air, in a due proportion to the quantity of fuel, and in such a manner that the fuel shall find, in the air which comes in contact with it, such a quantity of oxygen, that all the molecules of the fuel, which are capable of being combined with that constituent part of the air, shall unite with it.

In the month of June, 1785, Mr. Watt took out patents for several methods of consuming the smoke of furnaces; and as several modern patents present great similarity to Mr. Watt's, we shall here add nearly the whole of his specification, verbatim.

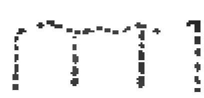
"I, the said James Watt, do hereby declare that the following is a particular description of the nature of my said invention, and in what manner the same is to be performed; that is to say, my newly-improved methods of constructing furnaces or fire-places consist in causing the smoke or flame of the fresh fuel, in its way to the flues or chimney, to pass, together with a current of fresh air, through, over, or among, fuel which has already ceased to smoke, or which is converted into coke, charcoal, or cinders, and which is intensely hot; by which means the smoke and grosser parts of the flame, by coming into close contact with, or by being brought near unto, the said in-

tensely hot fuel, and by being mixed with the current of fresh or unburned air, are consumed or converted into heat, or into pure flame free from smoke.

"I put this in practice, first, by stopping up every avenue or passage to the chimney or flues, except such as are left in the interstices of the fuel, by placing the fresh fuel above or nearer to the external air than that which is already converted into coke or charcoal; and by constructing the fire-places in such manner that the flame, and the air which animates the fire, must pass downwards, or laterally, or horizontally, through the burning fuel; and pass from the lower part or internal end or side of the fire-place, to the flues or chimney."

The annexed engraving represents a section of a steam-engine boiler, and its furnace or fire-place, which is an example of this method of heating or evaporating of water.

a is the boiler; *b* is a flue, surrounding the boiler in the usual manner; *c* is the "up-take," or passage from the



space under the boiler to the flues; *d* is a flue for the flame from the fire-place to the boiler; *e* is the ash-pit, and *f* a door to take the ashes out at, which must be continually kept shut during the time of working; *g h* is the fire-place. The fresh fuel is put in at *g*, and gradually comes down, as the fresh fuel consumes. About the middle of the fuel it is intensely hot, as it consists of coke or coals that have ceased to smoke. At *i* is an opening or openings to admit fresh air, and regulate the fire; *k* is a door into the space under the boiler, which being opened, admits air, and stops the draught of the chimney, when it is intended that the operation should cease. The fire is first lighted upon the brick arch *l*, and, when well ignited, more fuel is gradually added, until it is filled up to *g*, and care is taken to leave proper interstices for the air to pass, either among the fuel, or between the fuel and the front wall; and as much air is admitted at the opening *i* as can be done, without causing the smoke to ascend perpendicularly from *g*, which it would do, if too much air be so admitted. The dimensions of the various parts of the fire-place may be estimated by our engraving, which is upon a scale of a quarter of an inch to a foot; which makes the furnace ten feet from front to back. Mr Watt observes that the dimensions exhibited are adjusted for burning about eighty-four pounds of coal per hour.

"In some cases, after the flame has passed through the burning fuel, I cause it to pass through a very hot funnel, flue, or oven, before it comes to the bottom of the boiler, or to the part of the furnace where it is proposed to melt metal or perform any other office, by which means the smoke is still more effectually consumed.

"In other cases, I cause the flame to pass *immediately from the fire-place into the space under a boiler*, or into the bed of a melting or other furnace."

The annexed engraving represents a vertical section of a furnace for melting iron or other metals, with a similar kind of fire-place to the foregoing adapted to it, in which the same letters of reference as in the preceding figure indicate similar parts in this.

The specification states that—"in some cases, the part *g* of these fire-places is preferred sloping, and otherwise varied in form and proportions; but in all cases the same principle, that of placing the fresh fuel next to the external air, so that the flame or smoke passes over or through the coked or charred part of the fuel. Occasionally, the opening *g* is closed with a cover, to cause the air to enter wholly or principally at *i*."

The following figure exhibits another arrangement specified in the same patent, and the principle is deserving of attention, as other patents have been subsequently taken out for similar inventions, arising probably from ignorance of this, which the public should know is open to their adoption.

Mr. Watt observes,—"In some cases I place the fresh fuel on a grate, as usual, as at *a*, and beyond that grate, at or near the place where the flame passes into the flues or chimneys, I place another smaller grate *b*, on which I maintain a fire of charcoal, coke, or coals, which have previously burnt until they have ceased to smoke, which, by giving intense heat, and admitting some fresh air, consumes the smoke of the first fire.

"Lastly, be it remembered, that my said new invention consists only in the method of consuming the smoke, and increasing the heat, by *causing the smoke and flame of the*

fresh fuel to pass through very hot funnels or pipes, or among, through, or near, fuel which is intensely hot, and which has ceased to smoke; and by mixing it with fresh air, when in these circumstances; and in the form and nature of the fire-places herein mentioned, described, and delineated: the boilers and other parts of the furnaces being such as are in common use. And be it also remembered that these newly invented fire-places are applicable to furnaces for almost every use or purpose."

From the wording of Mr. Watt's claim, it is evident that he could not have sustained his patent, had it been disputed: the words we have marked in italics form a literal and exact description of Delasme's invention, just one hundred years before. This fact shows that Mr. Watt was unacquainted with the inventions and experiments of the French engineers to which we have adverted.

The next record of an apparatus for the consumption of smoke, since the date of Mr. Watt's patent, is the subject of a communication made to the Society of Arts, in 1790, by Mr. W. Pitt, of Pendeford, near Wolverhampton, wherein he describes a mode of converting the smoke arising from steam-engine furnaces into tar, with a view to prevent annoyance to the neighbourhood, and obtain-

ing a quantity of a very useful material. We make the following extracts from Mr. Pitt's letter:—

"That the object is not only attainable, will be demonstrated in the following narrative;—but also that valuable articles of commerce may be produced in large quantities, whenever the proprietors of such works shall adopt the mode of constructing their buildings proper for such production.

"The articles of commerce I allude to, are mineral tar, pitch, and varnish: there are already three considerable works erected on the banks of the canal in this county, for the purpose of converting the smoke of pit-coal into the above articles; the one at Mr. Wilkinson's great works at Bradley, another at Tipton, and a third at the level colliery and iron works upon Dudley-wood; they were erected by Lord Dundonald and Co., and the business is carried on with success.

"These tar-works are erected in the vicinity of large iron and coal works: the iron masters furnish the tar works with raw coal, gratis, and receive in return the cokes produced by such coal; and the proprietors of the tar works have the smoke only for their labour, and interest of capital.

"The process is conducted in the following manner:— a range of eighteen or twenty stoves is erected, and supplied with coal kept burning at the bottom; the smoke is conducted by proper horizontal tunnels, into a capacious and close funnel, of one hundred yards or more in length; this funnel is built with brick, supported by brick arches, and covered on the top by a shallow pond of water, which pond is supplied with water, when wanted, by a steam engine belonging to the coal or iron works; the chill of the water gradually condensing the smoke, it falls upon the floor of the funnel in the form of tar, and is conveyed by proper pipes into a receiver, from whence it is pumped into a large boiler, and boiled to a proper consistence, or otherwise inspissated into pitch: when the latter is the case, the volatile particles which arise during the inspissation are again condensed into an oil used for varnish.

"In this process the smoke is decomposed and destroyed, nothing arising from the work but a white vapour from some small funnels, (kept open to give draught to the fires), and a small evaporation of water from the pond, occasioned by the warmth of the smoke within the funnel.

"The process requires but little attendance, the principal labour being that of supplying the fuel. In any one of the tar works, the quantity of coal used is about twenty tons per day; three labourers, with a foreman, are sufficient for the whole business: the quantity of tar produced will be about twenty-eight barrels, of two hundred weight and a half, in six days, worth ten shillings per hundred; or twenty-one barrels of pitch of the same weight, worth fifteen shillings per hundred; though I was assured upon the spot, by a very intelligent person, that some coal is of so bituminous a quality, as to give one-eighth its weight of tar: but the quantity above stated is about the average produce.

"In order to bring the above practice within the Society's intentions, an alteration in the erection of steam engines, furnaces, &c. must take place; the alteration will be no more than that of erecting them below ground, instead of above: and when raising water is the main object, an adoption of the forcing or lifting pump, instead of the sucking pump, or the sucking pump may be still employed, wherever the fall of ground gives an opportunity of letting off the water raised, by an aqueduct; in which case, the lift being shortened, and less power necessary, ample amends will be thereby made for the expense of such aqueduct.

"Such kind of buildings, from a low situation within the earth's surface, will certainly acquire additional stability: and to those who are acquainted with the trifling expense of removing soil to small distances, the additional charge will appear trifling, and will be more than recompensed by such acquired stability. In some local situations, in hilly countries, the smoking works being erected at the foot, and the tar funnel higher up the hill, a communication may be effected without such alteration.

"I find by reports from other quarters, that successful attempts have been made to make coke of the coal employed in working steam engines; the additional improvements of making tar from the smoke, would not only prevent annoyance to the neighbourhood, but also apply to the best advantage every particle of that valuable and comfortable article, coal; prodigious quantities of which are at present wasted by being burned in one place for heat only, in another for coke only; when, by due attention, both purposes might in many cases be effected at the same time.

"I was informed on the spot, from undoubted authority, that the consumption of coal in Mr. Wilkinson's great works, at Bradley, is one hundred tons per day: about one-fifth of the smoke is actually employed in the making of tar; and the remainder, or the smoke of eighty tons per day, flies away. This, if collected, would yield upwards of eighteen barrels of tar, of two hundred and a half each; and if the smoke of the great works of the kingdom were in general collected for the same use, what a prodigious addition would it be, to the production of a commercial and necessary article, which always finds a

ready market, and will in many instances supply the vegetable tar at present imported from abroad!

"The tar works at present erected, are in an oblong form: it is probable, if the idea above described be adopted, a circular plan would be most suitable, somewhat similar to the drawing prefixed.

"*Explanation of the Plan.* *a* is the steam engine, the base of which suppose thirty feet below the earth's surface. *b b* the tar funnel, supported by arches, and covered with water, suppose the water fifteen feet above the earth's surface. *c c c c c* area sunk nearly as deep as the base of the building *a*. *d* gang-way, level with the earth's surface. 1, 2, 3, 4, funnels communicating from the main chimney to the tar funnel."

The following specification is descriptive of the next invention on record, which we insert verbatim, as the undefined manner in which the invention is described makes it somewhat hazardous to explain with certainty what were the exact arrangements intended.

The claims are however particularly worthy of notice, as shewing that the inventions of the rival disputants, who recently figured in a court of law, were in a great measure anticipated by the claims herein made.

Patent Method of changing the Smoke or Vapour arising from the combustion of many kinds of substances in various useful materials. By C. W. Ward, of Hatton Garden, London. 1792.

"Now know ye, that I, the said Charles William Ward, in compliance with the proviso in the said letters patent contained, do hereby describe and ascertain the nature of my said invention of a method of changing the smoke, or vapour, arising from the combustion of many kinds of substances into various useful materials, according to the substances burnt as follows. All smoke or vapour from the combustion of different bodies, is capable of being decomposed or condensed; but as the vapours, according to the substance they proceed from, require to pass through

cold water, the steam of boiling water, or to be confined some time in cold vessels, before they can be condensed, the change cannot be effected by any method hitherto known, because none of them are capable of making the vapour pass through water, or of confining it long enough to condense, without choking up the draught of air necessary for the burning of the fires. My invention supplies this defect, by making a constant draught from the fires, and causing the vapours to pass through, or be retained in proper vessels, a sufficient time for it to condense; this is effected by connecting the aperture of the chimney or chimneys with the condensing vessels or chambers, by means of tubes or pipes; then is to be placed, either between this connexion, or behind the condensing vessels, any machine, or machines, whose principle depends upon the known property of all fluids rushing in to fill up the vacuum caused by their action; that is to say, air pumps, water pumps, ventilators, bellows, air machines, &c.; these, however different their constructions, have all one common principle, and therefore the application of them, or others depending upon the said principle, to effect the purpose before-mentioned, will be an infringement upon my said patent; the size, number, and construction, of the condensing vessels, must depend upon the vapour to be decomposed, as some vapours are more difficult to condense than others, and therefore require a longer process.

"The apparatus being thus fixed, the substances to yield the smoke, or vapour, are to be set on fire under the chimney, or chimneys, and the machine or machines, set in motion by a steam engine, horse, water wheel, &c., the vapours will be drawn from the fires by the action of the machine, and made to pass through the condensing vessels to be decomposed. There must be apertures at the ends of the condensing vessels, if the pumping machine be placed between them and the chimney, to open and shut, for the purpose of giving vent to the incondensable airs, which will combine with the vapours in burning, and pass with them through the apparatus. If the machine be placed

behind the vessels, there will be no occasion for those apertures. In witness, &c."

No drawings are attached to the foregoing specification, and as it contains no defined plans that appear to have been reduced to practice, the information it gives does not extend beyond an explanation of the principle of the operation. We shall have occasion to make some further remarks upon this mode of preventing the issue of dense smoke from furnaces.

In 1796, a plan by Mr. William Thomson, of Bow Lane, Cheapside, was published in the Repertory of Arts, which appears to be the earliest furnace of that construction; we annex an abbreviated description of it.

The following figure represents a longitudinal and vertical section of the furnace, (and consequently of the boiler too, which has two horizontal flues running through it, but

not represented in our drawing); *b* the fire-place, which must be about one-third longer than they are generally made; *c* an arch which runs across the fire-place, two inches lower than the bottom of the flue under the boiler, and about the middle of the fire-place; *e* is the door of the fire-place, which is to have a small shutter in it. Through this shutter the coals must be gently stirred up, by the slice or poker, taking care not to injure the arch, nor to raise too great a quantity of coals at once; *f* is a small space left behind the fire, for a current of air to come through; adjoining which, at the extremity of the grate bars, there is a brick placed across the fire-place, to prevent the coals from falling over. There are two slides not shown in the drawing, the one to shift backwards, and the other forwards, to make the space *f*, for the current of air, larger or smaller, as may by practice be found best.

The operation consists in the arch *c* hindering the smoke from going up the chimney without passing through the fire behind it, which having a strong draught, burns the smoke as it passes through it: the air which comes up through the space *f*, being necessary to the complete combustion of it.

In 1801, Messrs. John & James Robertson, of Glasgow, took out patents for their improved furnace, in which it was stated that the smoke was completely burned. This invention has already been described by Mr. Galloway, in the first part of this work, page 145, which the inquiring reader had better peruse, before he proceeds further in this account. Messrs. Robertson's have the credit, (we cannot add whether justly or not), of being the first who succeeded in the project of economically burning the smoke. About this period, many manufacturers were indicted for nuisances, and compelled to adopt measures to remedy the inconveniences resulting from the escape of dense smoke; but notwithstanding the apparent simplicity of the process, very little success attended their endeavours, owing probably to the unskilful management of ignorant and prejudiced workmen. It was contended by the proprietors of steam engines, that the admission of fresh air, produced ignition

of the smoke, before it entered the chimney, had the effect of cooling the boiler, and that it required in consequence a greater quantity of fuel to work an engine. This objection confirms us in our opinion, that the want of success was owing to injudicious management; that more air was admitted than necessary to supply the requisite quantity of oyxgen to the carbonaceous matter, and that failure was not the result of any defect of the principle.

In the year 1812, Mr. William Evetts Sheffield took out a patent for improved reverberating furnaces for smelting metals, in which he introduced what he termed an *air-conductor*, for the purpose of conveying a stream of pure atmospheric air upon the surfaces of the metallic substances under reduction; but it appears, by the tenor of his specification, that he did not contemplate the application of the air conductors to the burning of the smoke of steam engine and other furnaces, which it subsequently proved very efficacious in performing.

This *air-conductor* consisted of a vertical passage or tube made in the bridge, or wall of brick-work at the back of the furnace, the lower end of which opened into the ash-pit, where it was widened, and the size of the aperture regulated by a valve, which valve was operated upon by a long rod passing through the front enclosure of the ash-pit; the upper extremity of the air tube or passage did not pass vertically *through* the bridge, but had a horizontal turn given to it, by which the jet was thrown upon the substances under operation, or against the current of heated vapours before they passed over the bridge; and this minor stream of fresh air was found to impart sufficient oxygen to the carbonaceous matter in the rising vapours from a coal-fire, to produce ignition and *burn smoke.* Thus was obtained an effect which was not contemplated by the patentee, as he only notices, in his specification, the utility of his plans in metallurgic operations.—We shall have occasion to make another remark on this furnace, after having described two or three others that follow in chronological order.

The annoyance and pernicious effects experienced by

the public from a sooty atmosphere, drew the attention of the legislature to the subject, about twelve years ago; and a select committee of the House of Commons was appointed in 1819, "to inquire how far it might be practicable to compel persons using steam engines and furnaces in their different works, to erect them in a manner less prejudicial to public health and comfort, and to report their observations thereupon to the House."

Unfortunately, however, the appointment of the committee did not take place until so late a period in the session, that the investigation did not proceed so far as was desirable; nevertheless, several persons were examined by the committee, whose minds had been long and practically directed to the extinction of the evil.

The committee having ascertained and reported to the House that the reduction of smoke from furnaces might be practically accomplished, a bill to embrace that object was brought into the House and passed, of which the following is an abstract:—

"*Stat. 1 and 2 Geo. IV. cap. 41, entitled,*

"An Act for giving greater facility in the prosecution and abatement of nuisances arising from furnaces used in the working of steam engines. To commence Sept. 1, 1821:

"Whereas great inconvenience has arisen, and a great degree of injury has been, and is now sustained by his Majesty's subjects, in various parts of the United Empire, from the improper construction, as well as from the negligent use of furnaces employed in the working of engines by steam; and whereas, by law, every such nuisance being of a public nature, is abateable as such by indictment, but the expenses attending the prosecution thereof have deterred parties suffering thereby from seeking the remedy given by law; Be it therefore enacted, by the King's most excellent Majesty, by and with the advice and consent of the Lords spiritual and temporal, and Commons in this present Parliament assembled, and by the authority of the same, That it shall and may be lawful for the court, before whom any such indictment shall be tried, in addition to the judgmont pronounced by the

said court, in case of conviction, to award such costs as may be deemed proper and reasonable to the prosecutor or prosecutors, to be paid by the party or parties so convicted.

"And be it further enacted, that if it shall appear to the court before which any such indictment shall be tried, that the grievance may be remedied by altering the construction of the furnace, or any other part of the premises of the party or parties so indicted, it shall be lawful to the court, without the consent of the prosecutor, to make such order touching the premises, as shall be by the said court thought expedient for preventing the nuisance in future, before passing final sentence upon the defendant or defendants so convicted."

It is also provided, that the provisions of this act shall not extend to steam engines employed solely in the working of mines, or smelting of metals.

Mr. Joseph Gregson, the first witness examined before the committee, stated his opinion of the principal causes of the nuisance to be, the putting on the fire, or into the furnace, too much crude fuel at one time, and the chimneys being in general too low. He was acquainted with several modes that had been practised to remove the nuisance, which had been done effectually under steam-engine boilers; but being generally attended with an *increased* consumption of fuel, it had seldom been adopted. In small boilers, where coke can be used instead of coal, the success had been more complete; but under large boilers, where a flaming fuel was required to act on all sides, Mr. Gregson was not aware of any plans that effected the object better than those which he had invented.

The principle upon which these plans were founded, consists, first, in causing all the smoke, after it has arisen from the fire, to return into the heat of the fire before it enters into the flue or chimney, and so be consumed; secondly, in putting on no more fuel at any one time than the smoke of which can be consumed; and that without opening the furnace door for the purpose; thirdly, in supplying every fire with a current of air, to counteract the effect of those winds that operate against the draught.

Mr. Gregson's Patent Furnace for consuming its own Smoke.
1815.

The above engraving represents a vertical section of the apparatus. The fire-place G, and the feeding-door F, are made as usual; the smoke passes over the bridge D, and under the said bridge is an aperture, through which a very intense heat passes, which enflames and consumes the smoke in the descending flue, by means of the supply of air through the aperture C; it then passes into the common flue or chimney A A, formed in the usual manner; Z Z is the air-shaft and drain to supply the fire with air, through a valve situated under the fire-place.

The next witness examined was Mr. William Moult, of Whitby, who stated to the committee, that "the former mode of heating the boilers, (at the Stowbrow Alum Works,) was by putting the coals over the bars in the common way; but my method is to make the flame come

over the coals, which are laid upon an iron *plate*, which lights the coals at the top, and the red part of the coal is next the bottom of the boiler; by that means the smoke, as it rises from the coals, is consumed in its passage over the bars. The consumption of fuel of the old boiler was regularly *eighteen* bushels of coals in twenty-four hours; but when altered in this manner, twelve bushels of coals produced a similar effect;—there was no more smoke than from a common chimney." Mr. Moult patented this furnace in 1815.

Our readers will observe that Mr. Moult's manner of feeding furnaces is now very commonly adopted. It possesses not merely the advantage of burning a great portion of the smoke, but in effecting an important saving in fuel, which may be accounted for by the circumstance of the small coals becoming ignited and cemented together, before they arrive upon the grate, through the bars of which a considerable portion of them would drop and be wasted, were they placed there in the first instance.

Although the evidence of Dr. Tuthill (who was the next witness examined by the committee of the House of Commons) does not relate to the description of any defined plan for the improvement of the construction of furnaces, yet, as it contains observations, facts and suggestions of an important and interesting nature, we feel ourselves warranted in inserting, in this place, a concise report of them. In answer to numerous questions, the doctor said, "I believe the atmosphere of London to be prejudicial to health; the accounts which have been published at different times, concerning the relative duration of life in London and in the country, may be considered as having proved that duration to be considerably diminished by a residence in this metropolis. It is probable that this depends upon the atmosphere of London. There are a great variety of causes, which contribute to render that atmosphere unfavourable to health; and I think we may be warranted in assuming, that whatever we can discover in such atmosphere, so as to render it different from that of the country, may contribute to produce this effect; and

therefore it becomes probable, that the quantity of carbonaceous matter suspended in it, is one of the causes of its insalubrity. The rapid advancement to recovery, which we frequently see in sick persons, during a short residence in the country, proves the influence which the atmosphere of London has upon health; there are many diseases incident to the human body, in which the influence of that atmosphere may be more easily detected, than in a state of health. In certain diseases of the lungs, especially, I think it may be proved that the smoke of London is prejudicial. I conceive that the fog peculiar to London, so different in its sensible properties from any fog in the country, depends upon the smoke of the metropolis, and is prejudicial in many diseased states of the lungs. The greater the quantity of carbonic acid gas, in a given volume of air, the greater would be the insalubrity of that air. But in crowded cities, the air is contaminated from a variety of other causes, which chiefly owe their origin to the exhalations, either from the living animal body, or from decomposing animal and vegetable matter, when the principle of vitality is extinct.

"I conceive the smoke arising from furnaces might be prevented; that is, that the carbonaceous matter which issues from such chimneys, and now mixes with the atmosphere, may be converted into carbonic acid gas.

"I think it can be effected, by making the smoke pass through an ignited tube, whilst the combustion of the soot is there assisted by a fresh current of atmospheric air. I see no reason why a simple apparatus may not be so contrived, as to render that combustion complete. But it appears to me to be deserving of consideration, whether this annihilation of smoke ought to be confined to manufactories. If, instead of burning common coal, that fuel were first divided, as it now is in the gas-light manufactories, into coke and carbonated hydrogen gas, and these were afterwards consumed in union, the brilliancy and warmth which we now enjoy by our fire-sides, would, to say the least, be undiminished, whilst the smoke would be entirely destroyed. This may be tried without any diffi-

culty, by the judicious admission of gas into a common grate filled with coke; the materials, in fact, would be the same as of our common fires, but employed in a state of greater purity. There is no limit to this mode of destroying smoke: and should a plan of this nature be hereafter adopted, chimneys, as they are now constructed, would be quite unnecessary; a small tube would be sufficient."

Mr. William Losh, of Newcastle-upon-Tyne, was next examined by the committee, on this important subject. Mr. Losh stated, that in several engines which had been erected upon his plans, the smoke was entirely consumed. These plans, which were secured to him by patent, dated April 8, 1815, (now expired, and open to public use,) he laid before the committee, and from these documents, together with a reference to the specification of his patent, we have compiled the following account:—

The principle upon which the mechanical arrangements are founded, consists in the application of the caloric evolved during the combustion, free from the cooling influence of any cold undecomposed air, in a sudden and equable manner, to the bottom of the boiler, or other vessel.

The plan consists in placing the furnace-bars as near as possible under the middle of the boiler's bottom, and to have the aperture or apertures for the escape of the rarefied air and smoke, above the door through which the fuel is put in; so that the heated air and gases, by their expansive force and diminished specific gravity, shall prevent the cold air of the atmosphere from penetrating beneath the bottom of the boiler, in order that the cold air admitted at the door where the fuel is introduced, shall, in its passage to the chimney, have no tendency to mix with the heated gases, until after they have ceased to act upon such parts of the boiler, as are required to be subjected to their action alone. A division of cast-iron plates, extending from the ends of the bars next to the door, separates the grate-room from the ash-hole and airduct, and prevents any air from passing into the grateroom which does not pass through the ignited fuel.

It is evident, that if cold air be permitted to have access to the bottom of a boiler, a larger fire, or an increased consumption of fuel will be requisite, to produce a given effect; and thus to maintain the steam at a sufficient expansive force to work an engine, an intense heat is applied, sufficient to flux the fuel into slags, and sometimes even to fuse the bars; but when this last effect does not take place, the temperature of the bars is usually so high, that the atmospheric air coming in contact with them, rapidly oxidates their surfaces, which fall off in successive scales, until the whole substance of the metal is corroded away.

An advantage therefore results from Mr. Losh's excluding the cold atmospheric air, which obviates the evil consequences just mentioned attending its admission. The position of Mr. Losh's fire-places likewise enable a more effectual support to be given to the bottom of the boilers, (an object of great importance when of large capacity,) than is practicable by the usual mode of setting them.

According to this plan, the caloric and heated gases ascend and radiate from the burning fuel, and impinge against the boiler with extreme velocity and intensity, as they meet with no substance to direct them from their course, or to which they can impart a portion of their heat; an economy of fuel seems to be a necessary result from this arrangement, while it affords a very expeditious means of getting up the steam to start an engine.

The specification of Mr. Losh's patent is very voluminous; besides a description of eighteen drawings, which accompany it, he enters largely into the theory of the subject, gives a history of his experience, his views, and his opinions, contrasting other plans with his own, which last are in all respects, of course, the acme of perfection. This document is obviously intended to serve the purpose of an advertisement, but from the talent and great experience of the writer it is, nevertheless, worth the reading. Our space will not permit us to describe only those plans which he submitted to the Committee of the House of Commons, in 1818. We commence with his furnace for

an oblong steam boiler, and shall next give his form of furnace for vessels of a circular form.

Patent Furnace for consuming Smoke under an oblong Steam Boiler, by Wm. Losh, of Newcastle. 1815.

(FIG. 3.)

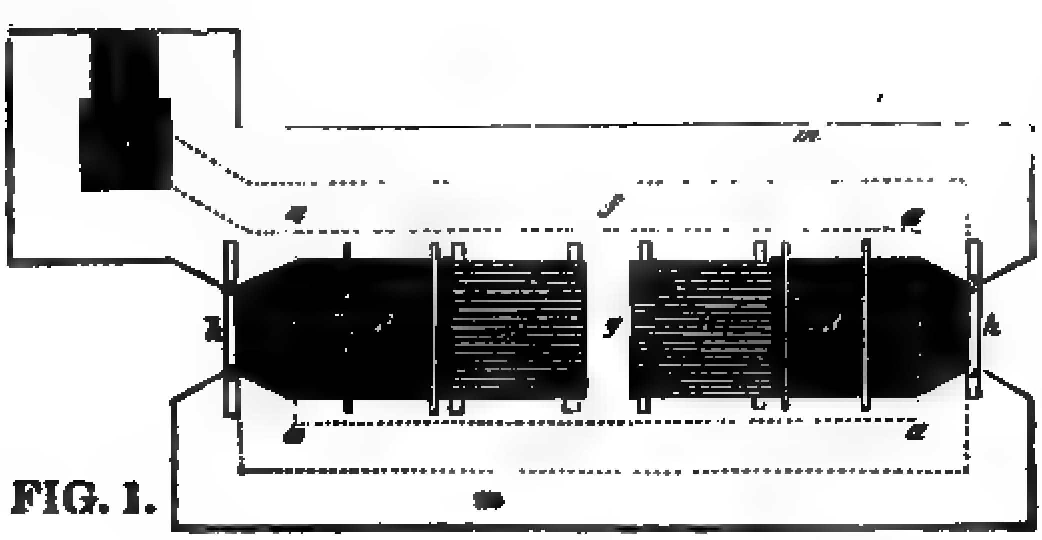


FIG. 1.

Fig. 1, is a plan or horizontal section of the furnaces for heating a steam-engine boiler, taken at the level of the grate bars; the area included within the dotted lines *a a a a*, shews that part above which the boiler rests when put upon its seat; *A* and *B* are the respective grate-bars of the two furnaces; *d d* the flooring plates, which prevent the air from penetrating from the ash-pit into the grate-room, except through the grate bars and burning fuel; these plates are supported by several bars, in case they should by accident crack; *h h* are the fire doors and frame; *g* the partition, which separates the two furnaces, and supports the bottom of the boiler; *f* the base of the chimney.

Fig. 2, is a vertical and longitudinal section of the boiler and brick-work, and furnaces; the letters in which refer to the same parts, as shewn in the plan. *g* the division between the two furnaces *A B*, *d d* the flooring-plates, below which are the ash-pits. The direction of the flames, from the combustion of the fuel in the grates, shew the course they respectively take to the flues *f f*.

Fig. 3, is a vertical and transverse section of the boiler, brick-work, &c. the letters of reference applying to the same parts as in the other figures.

N. B. Where it is of great importance to save fuel, it would be advisable to have register dampers on the ash-pits, by which the admission of the air might be regulated in the exact ratio required to keep up a due combustion of the fuel in the furnaces.

In order to burn the smoke effectually, it is to be made to penetrate with the atmospheric air through the burning fuel, by having dampers at *n* and *y*, (the apertures of the furnace *B* and *A* into the flues) perforations are also to be made through the flooring plates at *r* and *s*, with corresponding covers and doors, or registers, on the ash-pits at *p* and *q*.

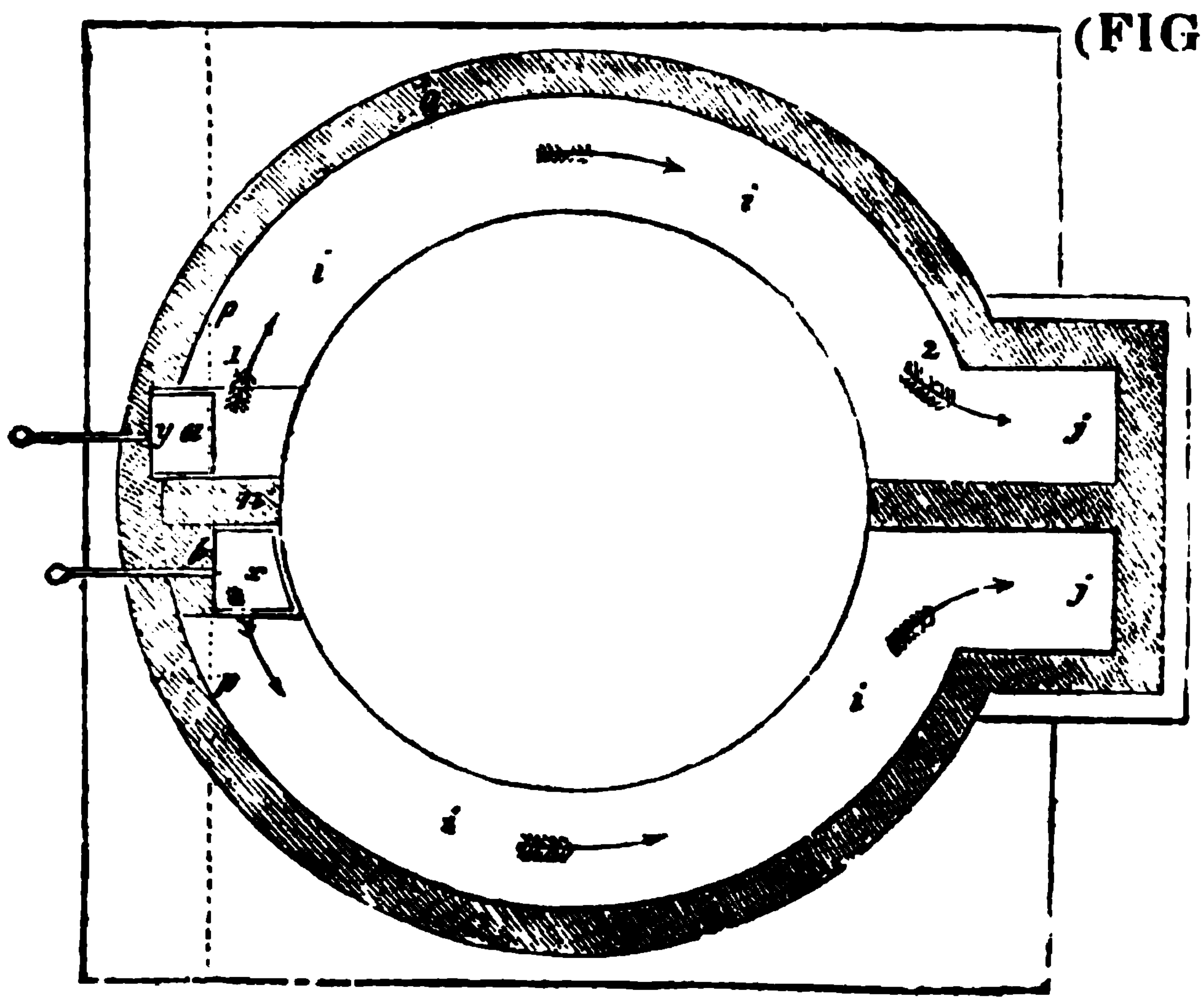
Suppose the fires to be burned bright, and that furnace *B* requires a fresh supply of coals, shut the damper *n* and open *y*, draw the cover of the perforated plate at *r*, and keep *s* shut; shut the ash-pit door, or register *q*, and open *p*.

Then must the soot which sublimes from furnace *B* pass into the ash-pit through *r*, and be carried with the current of atmospheric air, which enters at *p*, through the opening in the wall *o*, to the furnace *A*, where it will penetrate through the grates and fuel, and be converted into gaseous products. By reversing the operation of the damper, the dense products of furnace *A* may be consumed by *B*. When the smoke ceases to sublime, the furnace can, in a few seconds, be made to act as described above, by which there is a great saving of fuel.

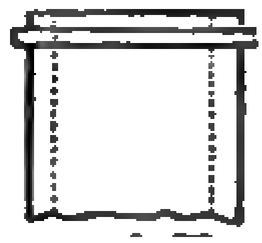
We now proceed to describe Mr. Losh's mode of constructing his smoke-consuming furnaces, under circularly-formed vessels; the drawings represent a sugar pan, but of course the arrangement under a round *boiler* would be the same.

Fig. 1, is a plan, or horizontal section, of the pan and brick-work, at the level of the bottom of the flues; *a b* shew the openings from the grate rooms into the flues *i i i i*, which convey the hot air, smoke, &c. to the base of the chimney *j j*, on each side of the division wall *n*, which also separates the two furnaces, and extends from the ash-pit diametrically across the pan, the bottom surface of which

(FIG. 1.)



(FIG. 2.)



lies upon it, with a bearing of four inches and a half wide. This wall rises three feet up the chimney, to keep the smoke, &c. of the two furnaces separated, till they have taken their perpendicular direction, and can no longer interrupt each other; *o o* is a circular wall, which surrounds the flue.

Fig. 2 exhibits a vertical section of the plan and furnaces; *a a a* shew the pan; *c* the grates and bearing bars; *i i*, the side flues; *l l*, the grate room; *o*, the circular wall; *n n*, the division wall, shewn as extending to the back of the pan, and up the chimney.

Fig. 3 represents a vertical section of the pan, and one of the two furnaces under it; *b* are the grate bars; *d d*, the flooring-plates; *i i*, the entrance into the side flues; *j*, termination of the side flue in the chimney; *m*, a sliding damper, to regulate the admission of air into the ash-pit, according to the quantity required to keep up a due com-

(FIG. 3.)

bustion of the fuel in the furnaces; *o* is the wall of the flue; *p*, a damper in the chimney; the arrows shew the direction of the hot air in the flues.

If it be required to burn the smoke, let there be dampers at *x* and *y*, (fig. 1), and a perforation of the wall at *z*, (fig. 2 and 3,) suppose both the fires, at *a* and *b* (fig. 1,) to be burned clear, and that *b* requires a fresh supply of coals, shut the damper *x* and open *y*; then the smoke which sublimes from *b* will be forced over *a*, and be burned in its passage. By reversing the action of the damper, the smoke from *a* may be consumed by the furnace *b*.

In adding fresh fuel, it is desirable to throw in but small quantities at a time, to keep the bars well covered, but in a thin stratum, and to allow the fire of the furnace last supplied to burn bright, before fresh fuel is added to the other; so that when one fire is at its highest degree of heat, the other

is at its lowest, in order that the boiler may be kept continually at nearly an equal temperature.

The specification embraces a description of a furnace to a locomotive engine, in which the heated gases alone are allowed to operate upon the boiler, without any admixture of cold atmospheric air; also the adaptation of the principle to alum pans, bleacher's and printer's boilers, baker's ovens, &c., all of which, the practical man, who has occasion for such apparatus, will do well to consult.

In the year 1818, Mr. W. Johnson, a Brewer, at Salford, near Manchester, was induced to make some experiments in the burning of smoke, and finally took out a patent for his plan, which we will endeavour to explain, without the aid of a drawing. The fire-place was on the plan of Mr. Moult's and Mr. Losh's, so far as to have a plate in front of the bars, whereon the coals were first deposited, and became more or less ignited, prior to their being pushed over the grating for their entire combustion. The air necessary to produce ignition of the carbonaceous vapour was introduced in the manner of Mr. Sheffield's, described at page 769, with this difference only, that Mr. Johnson allowed his current of air to impinge *vertically* by a passage made in the after-bridge against the bottom of the boiler, but he afterwards altered this, and gave the current a *horizontal* direction, exactly like Mr. Sheffield's.

Although Mr. Sheffield's and Mr. Johnson's invention possessed scarcely any originality worthy of notice, they were so nearly alike as to produce some sharp animadversions upon the latter gentleman, who was accused of piracy in some of the periodical publications, but the writers only exhibited their contracted knowledge of the subject in question. The consumption of smoke was then an object ardently sought after, in consequence of the notices made in Parliament, and in the Courts of Law, of the existing nuisances, arising from furnace chimneys. Numerous competitors, with "original and ingenious" devices, thrusted themselves before the public with their panaceas against the growing evil, all of them representing their apparatuses as the acme of perfection; and we believe it is true

that they did partially succeed in producing the desired effect, when the fires were managed by the skill and attention of the inventors themselves. It was evident that any plan that might be found super-eminently successful, would be productive of great emolument to the inventor. Accordingly we find numerous persons explaining and commending their plans to the committee appointed by the House of Commons; among these, were Messrs. Sheffield, Gregson, Losh, Moult and Johnson, whose plans we have already described; and we purpose adding those of Messrs. Steel, Brunton, Parker, Wakefield, Walker and Coombs. The inventions of Messrs. Losh, Steel and Brunton, it will be seen, possess the most originality, while all the others are but slight modifications of the previous inventions of Watt, Thomson and Robertson, whose patents were expired before these gentlemen came into the field. Notwithstanding this latter circumstance, they are not without merit, and the variously modified arrangements of furnaces in connexion with boilers which they exhibit, are calculated, we think, to afford many useful hints.

Furnace for the consumption of its Smoke, by John Steel, of Dartford.

This apparatus, which was denominated a *mechanical smoke-burner*, by the inventor, is shewn as adapted to the ordinary tubular high-pressure boiler, and is contrived so as to supply itself uniformly with fuel. We extract the description, from the report of the Committee of the House of Commons, to whom Mr. Steel gave his evidence on the subject.

The fire grate (of any suitable dimensions) is of a circular form, surrounding the centre piece P, moving on an upright axis, the toe of which turns in a centre C, and the upper end is supported by a cross-bar at L, which is made fast in the brick-work. E, is a fluted roller, for the purpose of supplying the fire with coal, from a hopper F, which should be furnished with a grating at top, so as only to admit pieces of coals of a limited size. G G, is an inclined

plane, set at such an angle, that the smallest of coals will slide down. At D, is a common toothed wheel, to be worked by a band, chain, or any other convenient mode of communicating motion. The fire door and frame may be situated in any convenient part of the circular frame, which will depend, in a great measure, upon the form of boiler to which the apparatus is applied; that represented at *o o o* in the figure, representing (as before mentioned) one of the tubular kind. N, is a metallic plate for the ashes to drop on. 1 1, show the ring or rim which surround the grate bars, and 2 2 the arms which support it and the grate bars. The rim is somewhat deeper than the bars, and turns round n an iron trough. 3 3, filled with sand or ashes, to

prevent the air from passing between the rim and the brickwork.

Now, suppose a fire to be lighted in the grate, and the grate and roller E, be put in motion, it is plain that such coals as lodge in the notches of the roller, will, as the roller turns round, be dropped on the inclined plane, and from thence scattered on a portion of the fire, as at R; and as the grate is moving round at the same time, another part of the fire is continually presented to each fresh supply of coals. The grate is made to turn round in such a direction, that the coals are immediately afterwards presented to the fire-door, which is therefore placed contiguous to it. At this part, the combustion is most vivid, from the ingress of air, and the fuel being scattered thereon, broken into small pieces, and the smoke having to pass over the whole surface of the fire, the combustible matter in it becomes consumed.

In using this furnace to boilers where there is no steam engine, any other mechanical power may of course be employed, or it may be turned by hand. Whenever the apparatus may be out of repair, it is only necessary to stop the wheel-work, which communicates the motion to the grate, which may remain stationary, and be supplied in the common way by a shovel, at the fire-door, until the disordered parts are put in repair.

The reader will observe a great similarity between this invention and that of Mr. Brunton, described farther on; we do not know to whom the precedence belongs, as they were made known to the world nearly at the same period of time (1819—20).

Mr. W. Brunton, of Birmingham, being examined before the committee, described, as introductory to his own invention, the "*usual*" construction of furnaces for burning of the smoke; which evidences the fact, that at that period of time, the fire-places in use were generally of the kind introduced by Mr. Moult and Mr. Losh, upon which we made some remarks in commendation, at page 19. Notwithstanding Mr. Brunton had a direct interest in pointing out the defects of previous inv[illegible]s, the re-

marks he makes upon them are well deserving of attention; accordingly, we shall here insert the substance of his evidence to the committee.

Mr. Brunton stated that furnaces for consuming smoke, as they were usually constructed, consisted of two distinct parts; first, the grate upon which the coal was consumed; secondly, the feeding mouth, into which the coal was put, preparatory to its being pushed forward upon the grate, at the end of the feeding mouth; opposite to that which joined the grate was fitted a door, in which were holes with covers, for regulating their apertures, by which atmospheric air was admitted at pleasure. The process was thus: whilst the coal already upon the grate was in high combustion, and had ceased to smoke, the coal in the feeding-mouth, being exposed to the heat of the fire, underwent a degree of coking, and the smoke was thereby evolved, which, combined with a portion of air admitted at the openings in the door, passing into the chimney over the hot fire, was consumed. When the fire was to be renewed, the coal thus acted upon was forced forward upon the grate, still carefully preserving a strong fire of well-burnt coal on the farther end of the grate, in order to consume the smoke, which would now be given out by the coal thus brought into active combustion; at this period a much greater portion of air must be admitted, than would be needful when the coal last forced forward had attained its full heat.

The following were the principal objections to the general adoption of this species of furnace:—"First, the process of coking, or preparing the coal in the feeding-mouth, was very imperfect, and but a small part of the coal necessary to feed the fire was affected by it, so as to give out less smoke when forced upon the grate; secondly, though the judicious admission of air to enable the smoke to ignite was found advantageous, yet a small excess admitted was found to have a very injurious effect in cooling the boiler; and as the quantity of air required for the combustion of the smoke must vary every moment of the interval b[illegible] the times of renewing the fire (perhaps

fifteen or twenty minutes), nothing short of the greatest care and unremitting attention to the admission of the air could accomplish the object with economy. This care on the part of the workmen could very rarely be obtained; and proprietors of steam engines have found that, for want of this, the burning of smoke has been too expensive for them to persevere in. The witness having turned his attention for some years to this subject, had discovered a method by which the smoke might be consumed economically, and its practicability was less objectionable than the methods usually adopted; first, by putting the coal upon the grate by small quantities, and at very short intervals, say every two or three seconds; secondly, by so disposing of the coal upon the grate, that the smoke evolved must pass over that part of the grate upon which the coal was in full combustion, and was thereby consumed; thirdly, as the introduction of the coal was uniform in short spaces of time, the introduction of the air was also uniform, and required no attention from the fireman. As it respected economy:—first, the coal was put upon the fire by an apparatus driven by the engine, and so contrived, that the quantity of coal was proportioned to the quantity of work the engine was performing, and the quantity of air admitted to consume the smoke was regulated in the same manner; secondly, the fire-door was never opened except to clean the fire; the boiler of course was not exposed to that continual irregularity of temperature which was unavoidable in the common furnace, and which was found exceedingly injurious to boilers; thirdly, the only attention required, was to fill the coal receiver every two or three hours, and clean the fire when necessary; fourthly, the coal was more completely consumed than by the common furnace, as all the effect of what was termed stirring up the fire (by which no inconsiderable quantity of coal was passed into the ash-pit,) was attained without moving the coal upon the grate. In a twenty-horse engine, the increased expense of the erection of his apparatus was from £75 to £100.

The apparatus alluded to by Mr. Bru[illegible] was in the

course of being patented to him about the same period of time. The specification, which was enrolled in December, 1819, describes the furnace to be of a circular form, and revolving in a horizontal plane, on a vertical axis in the centre of the ash-pit, under the boiler, by which means the heat is distributed uniformly over its bottom, and the fuel is supplied to the grate in regular quantities from a hopper placed above. Motion is given to the grate by means of a horizontal shaft and bevel gear underneath, and the speed at which it moves is at the rate of about one revolution per minute, for a boiler five feet in diameter. Every time the grate arrives at a certain point, the channel from the coal hopper is opened, and a sufficient quantity of fuel supplied. To prevent the air from passing at the edges or periphery of the revolving grate, a descending rim proceeds from it, which enters into a circular trough which is filled with sand or water, consequently all the air entering the ash-pit must pass through the bars; as the grate revolves, a scraper is carried round, which gathers up the ashes as they fall into the ash-pit below.

In the following year, 1820, Mr. Brunton took out a second patent for improvements in the arrangements of the last-mentioned apparatus. These improvements chiefly consisted in a means of raising or lowering the furnace at pleasure, so as to diminish the heat to the boiler suddenly; also, in a new mode of feeding the fire.

"The shaft of the circular fire-grate, or the axle upon which it revolves, is to pass through a hole as a guide, in a bearer of iron built in the brick-work, and receives its support at bottom, upon another bearer of iron, which is to be capable of sliding up or down in grooves, so as to elevate or depress the fire. To this last-mentioned bearer is to be attached a rack and pinion, or a lever, by means of which the grate may be raised and lowered at pleasure. Upon the upper end of the shaft, above the upper supporting bar, are extended two or more arms, carrying a strong ring of cast-iron, intended to receive the iron bars, which are to be placed parallel to each other, for the

grating of the fire; and round the periphery of the circular grate is to be a double rim of sheet-iron, rising three or four inches up, and forming a groove to be filled with sand; so that when the grate is raised, another ring of iron, attached to the wall of the furnace (built with fire-brick) may fit into this groove, and form a sand valve for the use of excluding the atmospheric air from passing up the sides of the grate. Two or more passages are made through the brick-work, for the purpose of admitting a current of air to the top of the fire, in order to assist in igniting the smoke, if necessary. These passages are to be opened or shut at pleasure.

"The fire-feeder is shaped as a hopper, placed over the feeding hole, and the delivery aperture at bottom is capable of contraction, as may be required. Below this is a plate of iron, placed in an inclined position, and suspended upon pivots, for the purpose of being agitated, in order to distribute the fuel, and supply the fire equally. There is also a shovel upon rollers, passing from a coal-box to the feeding hole, which is moved by means of a rod or chain communicating with the engine."*

In a subsequent sitting of the committee of the House of Commons to that which we have referred, Mr. Brunton stated that he had applied the improvements in his apparatus to several concerns with eminent success, and that they had uniformly effected a saving of coal, which, on an average, was more than 30 per cent.; and there was much less scoriæ or clinker formed from the same quantity of coal than in the ordinary fire, and that was formed in thin laminæ upon the grate; and, in general, while three bushels of coals per hour were consuming upon the grate, the bars were seldom so hot as to discolour writing-paper when pressed against them. By the very equal distribution of the coal upon the surface of the grate, a thin fire and a sharp draught was maintained; and this was effected by the coal being introduced in small quantities, falling upon the whole of the area of the fire in regular succes-

* London Journal of Arts.

sion. Secondly, the coal was introduced upon the fire without opening the fire-door, and this was effected by dropping the coal through the roof of the supplementary boiler. Thirdly, the decomposition of the coal was much more perfect than by the common furnace, and this was effected by the revolving of the grate, which exposed each side of every piece of coal in the grate to the current of the fire passing constantly in one direction across it. Fourthly, the introduction of the coal was completely governed by the steam generated, analogous to a water-wheel, governing by its velocity the quantity of the water permitted to fall upon it; thus, considering the production of the effect, and the introduction of coal as the cause, the former had a perfect check over the latter, and at no time admitted more coal into combustion than was really necessary for the performance of the work which the engine was then doing. Fifthly, the whole apparatus being a very simple mechanical arrangement, acted independently either of the skill or the carelessness of the fireman. Small coal, of greatly inferior cost to the coal generally used, answers well with a furnace of this kind, and thereby effects an important saving. A thin fire, with a sharp draught, produces the maximum effect, because the greater the quantity of oxygen brought into contact with the coal in combustion, the greater heat is obtained.

Smoke-consuming Furnace, by John Walker, Jun. of Kennington Cross.

The abovementioned individual was one of the witnesses examined by the select committee of the House of Commons, in 1819. He stated that, by his plan of heating the boiler of steam engines, a saving in the consumption of fuel to the extent of 75 *per cent.* was effected, resulting, in a great measure, as he explained, by employing coke as the fuel, and the preparation of that coke in an adjoining chamber or oven, the gases emanating from the coal being ignited by passing through the burning coke on the grate beneath the boiler, whence the heated air

and products of combustion took two turns round the boiler, before entering the chimney. Mr. Walker presented to the committee some drawings of his mode of constructing such furnaces, from which we have made the annexed copies.

(FIG. 1.) (FIG. 2.)

It does not appear, from the published report of the committee, that any explanations of the foregoing figures accompanied them, but we think the arrangement delineated will be clearly understood without them. Fig. 1, is evidently a longitudinal and vertical section of the boiler, furnace, and chimney; fig. 2, represents a transverse sec-

(FIG. 3.)

tion of the boiler and furnace; and fig. 3, a plan, or horizontal section, above the level of the grating for the boiler, including a section of the coke oven.

With regard to the expense of this kind of furnace, the inventor, who is a bricklayer, and therefore a competent judge, said, that in a new erection there would not be any additional expense above the common; and he would guarantee that there should be no expense incurred by the proprietor for three years after the building. The expense of altering furnaces to this plan would not be considerable; the amount would depend on the circumstances of the case. The expense of repairs, he observed, would be less upon his new plan than on the ordinary plans: the repairs would chiefly consist of new fire-bricks, when the furnace would last the same term over again.

Furnace for the Consumption of its own Smoke, by Benjamin Merriman Coombs, of 66, High Holborn.

Two plans were submitted by Mr. Coombs to the committee of the House of Commons, which are printed in

their report. The first-described plan is accompanied with six elaborate engravings, which, as we cannot transfer them to this place, we shall endeavour to give only a concise verbal description of.

The coals are put into a large hopper, above the furnace, and pass from thence between three iron cylinders, (the revolution of which reduces such coals as are too large to pass) down an inclined plane, falling upon a circular iron plate, placed near to the bottom of a cylindrical well or hole, which is directly underneath the boiler. This plate is made to slide up and down in the well, by the action of a toothed rack and pinion, affording the means of readily damping the fire, by depressing the bed of coals, which, together with the opening of the furnace-door, lowers the temperature immediately. The first heat of the fuel is directed upon a mass of iron, which becoming red-hot, consumes the smoke passing over it: there are also "Welch lumps" to receive the direct action of the fire, and ignite the smoke passing by them. The furnace being supplied with uniform quantities of fuel in a divided state, by means of the hopper and crushing-rollers, what falls upon the red-hot fuel is quickly inflamed, so as to produce but little smoke; and the fire is stoked, without opening the door, by means of a raker passing through a small hole, the furnace-man having the means of inspecting the progress of the fire through some small squares of talc, or Muscovy glass. Having explained the principal arrangements of this apparatus, we pass over the details, and proceed to the description of the other plan mentioned, which is represented in the subjoined cuts.

Fig. 1, exhibits a vertical section of a boiler and furnace:—*a* is the fuel hopper, to convey the coals into the front, or side of the fire. *b b* three iron rollers, to reduce the coals to a small size, and supply the fire with a uniform quantity, as the consumption requires. *c* is the front grating, and only aperture for air; the coals being always above the front bars, the air must pass through the fire and become heated. *d d* a massive lump of iron, with a

(FIG. 2.)

(FIG. 1.)

"return end," to receive the first heat; and *m*, an aperture through the same, for flame to pass, to assist and ignite the smoke that may pass through the internal flue *e*. *f* is the bottom of the boiler, and *g* the top. The back flue, which leads through the boiler, is cast of great thickness, as shown by the piece *i*, and that on the opposite side of the flue, the latter running through it; *k* the man-hole, for cleansing the internal flue; *p* is a damper; *s* a door to the ash-pit, made air-tight.

Fig. 2, is an end view of the boiler, the letters of reference thereon denoting the parts exhibited in the other figure.

Patent Boiler Furnaces, by John Wakefield, of Manchester. 1820.

This plan consists, as stated in the specification, in placing checks or stops in the flues of furnaces, for the purpose of impeding the progress of the flame and heated vapour, in order that time may be allowed to impart its heat to the boiler. The patentee observes, that, before the date of this patent, he was in the practice of introducing checks behind the breast of the furnace, at right angles to the sides of the bed, or bottom part of the flue. His present invention is stated to consist in making those checks which are placed in the farthest part of the flue to stand obliquely, inclining towards the front, by which the egress from the flue may be impeded. The checks consist of partitions of brick-work, extending from the sides of the flues to rather more than half-way across; their inclined positions causing the first pair to conduct the second pair, and to retain the heated vapour under the boiler, in a manner better calculated to produce the desired effect of heating the vessel, than if they were placed at right angles. The number of these checks so disposed, may be four or six, according to the length of the boiler. In the front of the breast, there is a curb or projection towards the fire, intended to impede the progress of the unconsumed smoke, which would otherwise pass off quickly with the heated vapour into the flue, and being deprived of its oxygen, would escape unconsumed. But by means of this curb, the smoke is arrested in its progress, and at the same time is met by a current of fresh air, supplied through blowers leading from the ash-pit to that part of the furnace, by which means it is forced back down upon the fire, and its combustion effected.

Another improvement described under this patent consists in placing the bars of the fire-grate radially, that is, much closer together in the front than at the hinder part. The advantage of this arrangement is, that the small coals are prevented from falling through the grating at the

time of feeding, and get coagulated together before they are pushed towards the farther part of the grate. This disposition of the bars, however, the inventor observes, he had exercised prior to the date of his patent, and therefore does not claim it, but has since introduced an improvement upon it, which forms a part of this patent, viz. instead of laying all the bars radially, he now lays from three to six of the bars (according to the width of the grate) parallel to each other, in the sides of the grate, placing the radial portion of the bars in the middle of the grating. The reason of placing these side-bars parallel, is for the purpose of allowing the teeth of a rake to be passed along the side of the grate, between these bars, by means of which the coals are pushed to the back part of the fire This rake may run in and out upon a roller, and rise and fall by pivots, and, if required, be worked by a rack and pinion, or in any convenient manner.*

Patent Smoke-consuming Apparatus, by Josiah Parkes, of Warwick. 1820.

This apparatus differs in a very trifling respect from its predecessors, yet the patentee having succeeded in getting it applied to the steam engines of several large works, obtained likewise the testimony of the proprietors of those establishments before the committee of the House of Commons; and through the medium of the latter, and its published reports, it acquired a celebrity to which (in justice to others) it was but little entitled.

The boiler is supported at its angles only, so that very nearly the whole of its bottom, and the lower portion of its sides, may be exposed uninterruptedly to the immediate influence of the fire. A large supply of coals is deposited in a space of twenty or thirty inches, left between the furnace door and the bars of the grating, for the purpose of being pushed forward upon the latter, by a long-handled instrument, without opening the door for replenish-

* London Journal of Arts.

ing the fire, which cools the boiler, and causes the emission of much dense smoke at the chimney. The ash-pit is uninclosed; at the back, a channel is cut through the brick-work, for the admission of a current of cold atmospheric air to the throat of the chimney, or that part of the flue through which all the smoke must pass, in its exit from the furnace; and this current is so directed as to drive back the vapour into the furnace, which inflames the combustible matter of the smoke. The lower end of the air channel, in the ash-pit, is provided with a flap-valve, which being operated upon by the handle of a long rod, extending to the outside of the front of the furnace, the aperture into the channel is enlarged or diminished, and consequently the supply of air may be regulated according to circumstances. The saving in fuel effected by this method of working a fire, is stated to be from 25 to 35 per cent.

Smoke-consuming Apparatus, by Matthew Murray, Leeds. 1821.

Most of our readers must have observed that the very lense black smoke which issues from the chimneys of steam engines is not constant; that it commences at the time of putting on fresh fuel, and continues for a few minutes afterwards. At this time, owing to the increased combustion, the air finds its way through the fuel with less opposition, and the evolution of dense black smoke ceases until the next charge of coals. To supply the requisite quantity of air to burn this black smoke, the late Mr. Murray devised a very ingenious machine. It is described in a letter, addressed to the editor of the London Journal of Arts, dated Feb. 15, 1821, where he observes—"The most effectual method yet known for consuming smoke, is by the admission of a large quantity of air to the hottest part of the fire, at the time the smoke is bursting from the recent charging of coal. The necessary quantity of air to be admitted ought not to be less than may pass through an aperture of *four square inches for*

each horse power that the boiler or fire is equal to. This will consume the smoke in from three to five minutes, according to the quantity and quality of coal put on at each time. The times of charging being not more than five times in an hour, nor less than three. The air's rushing into the flue, is the moving power for giving motion to my new regulating machine, which continues in motion during the consumption of smoke, but no longer.

"By this method there is no unnecessary loss of heat, as, when the aperture is left open, or the shutting it off is entrusted to the uncertainty of neglect, which is the case if regulated by hand, and from whence a great loss of fuel is the consequence."

The opening of the fire-door, to admit the fuel, puts the machine in a state for measuring off the quantity of air to be admitted after each charging; drawings and descriptions of this apparatus are given in the beforementioned work, vol. ii. but we will here endeavour to afford the reader an idea of it, without drawings.

The machine consists of a sheet-iron box, containing a light fan-wheel, from which proceeds a capacious tube, communicating with the fire-place, and containing a turning valve, which opens or closes the passage; the mechanism through which these operate we will explain, with its mode of action.

When the fire-door is opened to take in fresh coal, it discharges (by means of a wire and slip catch connected to the door) a pall, which sets at liberty a suspended weight, which by its descent turns a ratchet-wheel one revolution and a quarter, which places the turn-valve edgeways against the current, and leaves a free communication between the atmosphere and the upper side of the fire. In this state of rest the machine remains, until the fire-door is shut, when the current of air enters the machine, turning rapidly the fan-wheel, which having a pinion on its axis of only one tooth, gives a slow motion to a light spur-wheel of many teeth; this wheel, through the medium of a catch-rod and other simple mechanism, gradually closes the turn-valve; the smoke having been

consumed, the fire continues burning, until a fresh supply of fuel is necessary, when the fire-door is opened, and the whole operation is repeated.

Patent Apparatus for Consuming Smoke, by W. Pritchard, of Leeds. 1821.

The patentee states, in his specification, that he has observed that the admission of fresh air into the furnace is necessary to the consumption of smoke; "and that if the doors, or air-flues, are not closed in proper time, the cold air will cause a more rapid combustion of coal than is necessary or consistent with economy, as well as tend considerably to increase the wear of the boiler. From which circumstances he has been induced to adopt this, his simple and new invention, whereby a self-adjusting or self-regulating apparatus is produced, which will cause the fire-doors or air-flues to become closed in any required space of time, without depending upon the care of the man who attends to supply the fire with fuel."

The apparatus consists of a small cylinder, placed in any convenient part of the boiler house, having an air-tight piston to rise and fall within it. At the upper end of the piston-rod a chain is attached, which passes over pullies, and at its reverse end is connected to the top of the fire-door or air-flue doors; by means of which connexion, when the fire-door is raised, the piston descends in the cylinder by its own gravity, and when the fire-door is shut down, the piston rises. On the outside of the cylinder is placed a branch pipe or channel, through which the air passes (as the piston ascends or descends) from the upper to the lower part of the cylinder, and *vice versa*. In the midway of this branch pipe is a valve or stop-cock, which may be so adjusted as to suffer the air to pass slowly, or by a very small stream, through the channel; by which means the ascent of the piston is retarded, and hence the entire descent, or closing of the fire-doors, or air-flues, does not take place until the air is nearly all expelled from the upper part of the cylinder, allowing time for the

requisite quantity of atmospheric air to pass into the air-flues, or over the fire, for the purpose of consuming the smoke; which time of closing the doors is regulated, as above, by the valve or stop-cock in the branch pipe.*

Patent Furnace for Consuming Smoke, by George Stratton, London. 1822.

This patented contrivance may be considered as a modification of Mr. Watt's plan, described at page 761, wherein two fires are employed. Mr. Stratton's specification exhibits an oblong boiler, set in a furnace, to which two fire-places are adapted; one of them is in front of the boiler, being supplied by a funnel from above, of the shape of an inverted cone, which is surrounded by water, and there is a common fire-door in front, to be used whenever necessary to have access to the burning fuel. At two-thirds of the length of the boiler from the front, another fire-grate is fixed, and the coals are supplied to this by a similar conical funnel to the before-mentioned, which passes through the boiler.

The fire is to be first kindled on the bars of the interior grate, by dropping thereon the necessary fuel from above, through the boiler, the fuel being continually added until not only the fire-grate is charged, but the inverted conical pipe also entirely filled, forming thereby a cone or pyramid of coals, extending from the grating to the top of the boiler, where an air-tight cover is put on the funnel-feeder, to prevent the escape, in that direction, of any of the products of combustion. The fire in the front of the boiler is next lighted, and the coals heaped up in like manner, by entirely filling its funnel feeder, which is closed at its upper orifice by another air-tight cover. The air is admitted from the ash-pit of this fire, which passing through the bars and the burning fuel above, the current of flame and smoke, in its course to the chimney, is carried through the more intensely ignited fuel of the second fire,

* London Journal of Arts.

where, the *specification* states, the smoke is entirely consumed. Instead of metal caps to the funnel feeders, Mr. Stratton proposes, in some cases, to adapt hoppers to their superior orifices, furnished with sliding valves.

It does not appear that this patentee thinks it necessary to introduce any fresh atmospheric air to the smoke from the first fire, which will of course need a supply of oxygen for its combustion.

The claim made by Mr. Stratton, in the specification of his patent, is as follows :—

"My said apparatus may vary in its dimensions and proportions, to suit the situations to which it is applied; but an apparatus applicable to fires, which *causes the smoke from fires to be consumed, by preventing its escape from the fuel in any direction, except through the immediate body of the fire, which generates it, thereby exposing it to such an intense heat as will consume it*, and capable of being added or attached externally to almost any part of any shaped boiler, being, to the *best of my knowledge* and belief, entirely new, and *never* before adopted for that purpose in this kingdom, I intend hereby to maintain an exclusive right and privilege to my said invention."

This claim, though worthy of remark, is by no means singular or extraordinary, for it only exhibits the same want of information on mechanical subjects, and the same incorrect mode of defining the thing invented, which pervade the greater portion of the specifications of patents! It is however very remarkable that the patentee, who has been a furnace-maker the greater part of a long life, should, *first*, claim for his "said invention" a totally different thing to that described and delineated; the latter is shewn to consist of two fires, in which the smoke generated by the first is consumed, (or intended to be so) by the second, while the *claim* is for consuming the smoke by the "*immediate body of fire which generates it!*"—*second*, that a man of his experience should re-invent and describe a very inferior modification of previous contrivances, to which the utmost notoriety had been given, by patenting and publishing in periodicals and pamphlets (we allude in

particular to Mr. Watt's and Mr. Losh's inventions)—and, *thirdly*, that he should, notwithstanding these circumstances, exclusively claim for his invention that which was, previously, even more extensively known and used than that which he described!

Patent "Fuelling Apparatus," by John Stanley, of Manchester. 1822.

We have now to describe an apparatus, in which a self-regulating mode of supplying furnaces with fuel is introduced; and it is one that we know has been extensively and successfully reduced to practice. It forms a distinct appendage to the front of the furnace of any ordinary boiler, to which it makes a very neat finish. At the upper part is a hopper, containing a supply of *small* coals, sufficient for an hour or two's consumption. Through an aperture at the lower angular extremity of this vessel, the coals drop between two grooved rollers, which, revolving in opposite directions, break the pieces of coal which are too large to pass through without being crushed, (the distance between the rollers determining the dimensions of the pieces of coal, which is regulated at pleasure by turning a set-screw.) After passing between the rollers, the coals fall upon a flat plate of iron, whence they are continually projected by a revolving fanner, which scatters them over the burning fuel on the grate, where it lies in a thin bed, in order that the air may have a more free passage between the bars; against the bridge of the furnace, however, the fuel is collected in a deeper mass that has ceased to flame, and the small quantity of smoke rising from the fresh fuel in passing over the bridge becomes in consequence inflamed and consumed. The motions of the crushing rollers, and the fanning distributor, are of course communicated from the engine through the medium of suitable common gear, placed outside of the feeding apparatus.

The patentee, at the conclusion of his specification, limits his claim of invention in the following manner:—"I do hereby declare, that my invention consists in the employ-

ment and application of the *fan*, similar to the one hereinbefore described, in conjunction with the hopper, fluted roller or rollers, or with any other mechanical expedient, capable of producing a regular supply of coals, so that the coals so supplied may be, by the fan, as aforesaid, thrown upon the fire or furnace."

We have had an opportunity of observing the application of this very excellent invention to a large engine at the South Lambeth Water-works, to which two forty-horse boilers are provided. Previously to the adoption of Mr. Stanley's apparatus, it was found necessary (as we were informed) to use both these boilers at one time, in order to obtain sufficient steam to do the work, and the labour of the fireman was at that time found excessive, in supplying the fuel by hand. Now, however, the feeding of the fire is performed without manual intervention, and the effect of the fire thus mechanically supplied, is so much greater than before, that only one of the boilers, instead of both, is found fully adequate to supply the steam. The quantity of fuel required is, besides, so nicely regulated by the engine itself, that the instant there arises an excess of steam in the boiler, the feeding apparatus ceases to work, by being thrown out of gear, and when the steam falls below the required pressure, the falling of the mercury puts the machinery into gear again, and the feeding with the fuel recommences. The large coals being broken by the rollers to a sufficiently small size, ignition takes place almost at the instant they are received into the furnace, and very little smoke being given off, there is but little requiring subsequent combustion. The mechanism required to give efficiency to this apparatus, when viewed as a whole, gives it an elaborate appearance; yet the several combinations, taken distinctively, are so simple, and adapted to their object, that the liability of derangement and the cost of repairs must be trifling; on this point we were informed that the engineer who put it up, (Mr. T. Thomas, of Holland-street, Blackfriars, London, agent to the patentee,) offered to keep it in repair for 2 per cent. of the first cost, per annum.

Patent Method of Condensing Smoke and Metallic Vapours, by Mr. Humphrey Jeffrey, of Bristol. 1824.

The highly pernicious, and even deleterious effects produced upon the inhabitants, the cattle, and the vegetation, in the vicinity of works for the smelting of copper, lead, and other ores, led the patentee to devise the following plan of a flue, as a remedy for the evil, which may be applied to any description of furnace, for the condensation of smoke, where a supply of water can be conveniently obtained.

The above figure gives a vertical section of the patent flue. *a* represents a common flue, proceeding from any description of furnace; the top of which being closed, the vapour proceeds along the horizontal branch *d*, into the condensing shaft *b*; on the top of this second shaft is placed a cistern of water, the bottom of which is perforated with numerous small holes; and being duly supplied with water, a constant shower, like fine rain, is produced, while the furnace is at work. The showering of the water uses a strong draught, by which the vapour is drawn into

the current, and immediately condensed. The several matters thus condensed, (particularly sulphur, in large quantities), run off with the water through the passage *e*, into recipients suited to the nature of the products obtained by the operation. When only one common wall divides the smoke passage from the condensing shaft, a hole through the wall of the same area as the chimney, will answer equally well.

Furnace for Consuming Smoke, by Mr. George Chapman, of Whitby. 1824.

It being a well-established condition, that a portion of pure atmospheric air must be admitted, to unite with the smoke after it is generated in the furnace, in order to supply the oxygen gas, without which it will not inflame; and it being an equally established fact, that any air admitted into the body of the furnace, if it does not go through the burning fuel, has a great tendency to cool the boiler, and retard the generation of steam: to obviate this, it had been the general practice, in the construction of furnaces to consume the smoke, to admit the air partly at the ash pit, and partly up through the fire-bridge. By Mr. Chapman's plan, however, the air is heated before it enters the furnace, in the following manner:—

The grate-bars are cast hollow, from end to end, so that they form a series of parallel tubes, which open into two boxes, one placed in front, and the other behind the grate. In the front box, directly underneath the fire-door, there is a register to open and shut, to any extent, at pleasure. The other end is connected with the brick-work, directly under the fire-bridge, which fire-bridge is made double, with a small interval between, about one inch, the interval to go across the furnace from side to side, and rather to incline forward, or towards the fire-door, so as to meet and reverberate the smoke on to the ignited fuel in the grate, which causes it to inflame and become a sheet of bright fire under the bottom of the boiler.

From the foregoing it will be perceived, that if the front register is open, or partially so, there will be a great

draught of air through it, along the interior of the grate-bars, thence into the flue of the fire-bridge, and out of the orifice at top, which air will be heated in its passage through the bars, before it comes in contact with the smoke, when it will give out its oxygen, and cause it to inflame.

In a letter to the Society of Arts, from whose "Transactions" this account is taken, Mr. Chapman observes, "Such was my view of this part of the subject in theory, and I have found it to succeed in practice, in a small engine of my own. But a further improvement was necessary, to make it quite perfect. There are few people who are aware of the extent of the mischief arising from the old method of charging a grate by the front door. Now, in my engine (which is only two-horse power,) I calculated that every time the fire-door was opened, to stir the fire, and replenish the fuel, there could not be less than from 45 to 50 cubic feet of cold atmospherical air admitted into the furnace, which so cooled the heated gases, &c. that, however complete the plan was in other respects, the smoke could not possibly inflame from being so cooled, till a considerable time after the fire-door was shut.

"To obviate this, I have adopted a cast-iron hopper above the fire-door, with a type at the bottom that has two pivots at one side, and opens at the other; one pivot goes through the end of the hopper, and has a counter lever to keep the type shut, when a sufficient quantity of coal for a charge is on it. The top of the hopper is covered with a lid, which I shut down during the time of firing; then, by lifting the lever which opens the type inside, the coals slide down on to the fore end of the grate-bars, which is only the work of a moment. It is evident that no quantity of cold air can thus get into the furnace; in fact, it is not possible for any person that does not see the operation of firing, to know when fresh fuel is added, by looking at the top of the chimney. The smoke that issues is never more than a light grey, just perceptible, but in a general way is not seen at all.

"The coals last admitted, after lying a short time at the front of the more ignited fuel, become partially coked,

and just before I admit a fresh supply, I push the last charge further along the grate, by a tool made for the purpose, which remains constantly in the furnace. It consists of a plate of iron, about four inches broad; its length goes across the grate, with a round bar of iron riveted in its centre, at right angles, to form a handle, which comes through a hole made in the bottom of the fire-door, and is long enough for a man to use with both hands, so that he can either push from or pull towards him, to manage the fire within, without opening the fire-door, except when the grate wants cleaning, &c. &c. For better knowing when the fire wants stirring or replenishing, I have a hole, about an inch in diameter, in the fire-door, to look through, covered by a piece of iron, which hangs by a rivet above.

"After I have used the above instrument, I pull it up close to the fire-door, where it remains till it is again wanted; and the coals, when let into the fire, fall down beyond it.

"The above-written account constitutes the whole of my improvements, as far as is required by the Society, but not the whole of the advantages gained by my invention. For instance, the *durability of the grate-bars*, by the admission of air through them. I may add that I examined my own yesterday, and I do not find them any worse, although they have been in use since the beginning of October last (1824)."

Mr. Chapman concludes his letter by referring the Society to the certificates, which accompany the communication, of several scientific gentlemen of Whitby, all of the highest respectability, whose attestations confirm the statement of the inventor in every important particular.

Reference to the Engravings.—Fig. 1, is a section of the boiler and furnace; and fig. 2, a view of the hollow bars as they open into the box *i*.

a is the boiler, *b* the fire-place, *c* the feeding hopper, with its cover *d*, and its type or turning bottom, with its lever or counterpoise *e*, by means of which the coals are delivered into the fire-place. *f* is a rake, by means of

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which the half-burnt coals are pushed forwards previously to letting in a fresh charge; *g* a slit below the furnace-door, through which the shaft of the rake passes; *h* an eye-hole in the furnace-door, through which the state of the fire is seen; *i i* an air-tight box, into the back of which the bars open, and in front of which is a register for the admission of air; *k* one of the hollow bars, the whole of which are shown in fig. 2, as they open into the box *i* above-mentioned; *l* a flue in the fire-bridge, through which the air having passed into the box *i*, and thence through the hollow bars *k*, passes into the furnace and consumes the smoke.

For the communication of the foregoing invention to the Society of Arts, the Society awarded Mr. Chapman an honorary medal.

Mode of obviating dense Smoke, by Mr. R. Evans, of Queen Street, Cheapside, London. 1824.

The constituent gases which form water (oxygen and hydrogen) being powerful supporters of combustion, it has been attempted by Mr. Evans to render them available for that purpose by decomposing high-pressure steam, by causing it to pass through the strongly-ignited fuel of the furnace. The apparatus used by Mr. Evans for this purpose is delineated in the preceding cut, where A represents an end view of the boiler, of a cylindrical figure, set in brick-work in the usual manner; B is the internal fire-place, contained in a large tube denoted by the dotted circle; C is the ash-pit; *d* a branch from the waste-pipe of steam engine; *e* a stop-cock; *f* is the feeding tube, pierced

with numerous small holes, through which the steam escapes in little jets diffusing itself over the surface of the underneath part of the fire, whence in passing through the burning fuel it becomes decomposed. The fuel employed is coke, which gives off little or no flame, when the steam-feeding apparatus is not used; but immediately the cock *e* is turned, a powerful flame, as represented at *g*, is produced, presumed to be from the burning of the hydrogen, resulting from the decomposition of the water. Without entering here into the discussion whether any increased effect is produced by the "burning of the steam," there can be no doubt of a great advantage resulting from its application in blowing the fire, which it manifestly excites, and raises the steam to much greater elasticity, as we had an opportunity of witnessing.

Mr. Evans's premises being situated in a closely-built part of the town, he tried every means in his power to obviate all annoyance to his neighbours, from the emission of dense smoke from the chimney of his steam engine. With that view he first made trial of coke in his furnace, but was under the necessity of relinquishing it, finding that he could not therewith raise the steam beyond eighteen or twenty pounds upon the inch, however unsparing he was in the quantity of coke employed; he therefore resorted to the use of coal to obtain the required work from the engine. Subsequently, however, it occurred to him that he might use his waste steam as an auxiliary to combustion, and he devised an apparatus of the kind we have just described; he now tried coke again, and the result exceeded his most sanguine expectations, the steam being kept up steadily to about thirty-five. The quantity of coke consumed was from six to six and a half compared to five of coals, consequently reducing the expense to nearly one half.—Mr. Evans has satisfactorily proved, by the constant use of this apparatus during five years, its economy in saving expense of fuel, and its indispensable utility to himself, in entirely obviating the necessity of creating any dense smoke.

Mr. Evans found that a considerable quantity of water

was reformed, after passing through the furnace, which obliged him to have a cistern fixed at the bottom of the chimney to collect it.

Patent Furnace-feeding Apparatus, by James Barron, of Birmingham. 1826.

The object of this invention is to feed the furnace with fuel, without opening the furnace door, and in causing all the air admitted to support combustion to pass through the grate bars. A large tube is erected in a vertical position nearly over the furnace; this tube is divided into several compartments, one over the other, by falling bottoms, and having openings at the sides; opposite to each of these openings is a box or tray, charged with coal, suspended upon pivots in a vertical frame, in connexion with a train of wheels that by their revolution draw up a sliding bar; which bar, by means of a click, successively turns over the equipoised boxes of coal, into one of the compartments of the tube, the falling bottom in which now giving way, discharges the coals through the tube on to an inclined plane or shoot, which distributes them upon the grate. The bottoms of the several compartments, in falling by the weight of the coals, depress the upper end of a long lever, the lower end of which, formed into a rake, is thereby caused to ascend and rake out the ashes from the fire bars from underneath, just previous to the distribution of the fresh fuel. In this manner the furnace is fed with small quantities of fuel, and at uniform periods of time apart.

Patent Furnace Grates, by Mr. Jacomb, of Basinghall Street, London. 1826.

The principal intention of the inventor was the construction of grates for domestic use, but he includes in his specification a notice of their application to steam boilers. The furnace consists of a cylindrical cage of bars, in which the fuel is put at the top, and the cylinder is then turned half a revolution on its bearings, to bring the fresh fuel

under the ignited, causing the smoke from the fresh coal to pass through the ignited portion, and be consumed. The following description is extracted from the third volume of the Register of Arts.

"Fig. 1. represents an elevation or side-view of the cylindrical furnace, (or stove-grate,) supported upon its hollow axis *a a*, which rests, and revolves when required (as will hereafter be described) on the supports *b b*. The external horizontal bars, which contain and constitute the support of the fuel, are rivetted, or otherwise fixed to the circular ends *c c*. Fig. 2. gives an end view of this cylindrical furnace, by which it is shewn that the cylinder is closed at one end, and divided into equal portions, or compartments by the bars, *d d d*, at the other end; these divisions extend the whole length of the cylinder, so that the

furnace is thereby divided into three (or it may be any number of) distinct compartments, into which the doors *e e e*, severally open and communicate. *a* represents the interior hollow axis, which is likewise connected by bars from end to end; through this opening *a*, air is admitted for the support of combustion, and for the requisite stoking or clearing the fire of ashes and other residuum, as well as for the introduction of steam, tar, or other material, for increasing the combustion. Fig. 3. is a plan of one of the end circles or frames *c c*, with the arms *d d d*, as before described.

"In putting the apparatus described into operation, when applied to a boiler for generating steam, it is to be placed within a flue or passage through the boiler, so formed as to admit the apparatus to revolve on its axis, with the feet *b b*, resting on the bottom of the flue; and it should be inserted so far within the flue, that the end at which the fire-doors *e e e* are fixed, should be flush, or parallel to the outside of the boiler, as shewn at fig. 4. In this position, the whole of the space between the exterior and interior cylinders are charged with coal, coke, or other fuel, and the uppermost portion is then lighted or fired, air being admitted through the open end of the cylinder *a*, and through the bars of which the same is formed. As soon as that portion of the fuel contained in the uppermost compartment is burned to that state in which it gives off no more smoke or vapour, the whole cylinder is to be gradually turned in its hollow axis, in order that a portion of the fuel contained in the adjoining compartment may also become ignited. By this action it will be seen that the smoke, generated by the lighting of that portion of the fuel beneath, or immediately contiguous thereto, is compelled to pass through the first lighted portion, and is thereby consumed.

"When fresh fuel is required, it is to be thrown into the uppermost division, through the door *e*, and upon the top of the ignited fuel contained therein; the cylinder is then to be turned on its axis, so as to bring the fresh fuel under that which is ignited, the cylinder being turned as often as may be required, o keep the live fuel on the top.

"By this arrangement it will be observed, that all the component parts of the coal are made available for the production of heat, and the draught of air conveyed to the centre of the fire in any quantity, and which may be regulated to the greatest nicety through the centre of the cylinder.

"The rotary motion occasionally given to the furnace is to be effected by a lever, inserted in the holes on the end of the axis, shewn at *c c*, fig. 1, or by some other simple mechanical contrivance, the nature of which will depend upon the size and situation of the apparatus."

Patent Boiler Furnace, by James Gilbertson, of Hertford. 1828.

The title of this patent expresses it to be "an improvement in the construction of furnaces, by which they consume their own smoke," and we doubt not that it is as well calculated for that purpose, as many others which we have described; the novelty of its arrangements are however but slight. In most of the previous contrivances, the air to burn the smoke given off from the fuel on the grate, is admitted at the back of the fire from the ash-pit, or it is conducted through the bars of the furnace, which are made hollow for that purpose, as in Mr. Chapman's invention, recently noticed. Mr. Gilbertson's plan is to heat the air thus supplied by causing it to pass between "hollow-plates," fixed at the sides of the furnace, and thence into a cavity at the back of the fire, where, ascending through a grating above, it comes in contact with the smoke and causes it to ignite. The "hollow plates," are adapted to afford a greater volume of air than Mr. Chapman's hollow bars, and the increased conducting surface to convey the heat, as well as their more favourable position to absorb the heat, are deserving of consideration. The admission of more air than is necessary to supply the required quantity of oxygen, being attended with loss of heat to the boiler, suitable valves or registers shou d be provided to regulate the quantity.

American Patent Furnace for generating Steam by Anthracite Coal, by B. Howell, Philadelphia, 1828.

As anthracite contains no bituminous matter, and emits no smoke during combustion, the employment of that coal alone would completely obviate the nuisance of a sooty atmosphere. Extensive beds of this mineral exist in various parts of Great Britain, and, very conveniently for commerce, in South Wales. The Americans, from a species of necessity, have managed successfully to bring it into use for a variety of purposes, to which it was thought wholly inapplicable. It is our business, in this place, to lay before the reader an account of Mr. Howell's application of it to the generation of steam, which we derive from the specification of the patent, contained in the "Journal of the Franklin Institute."

The improvement claimed, consists in the form and principle of the interior of the furnace, and in its being a separate structure from the boiler, or other body to be heated, by the means of which the heat is generated without bringing the fuel in contact with the boiler or other body; and in the application of an artificial blast upon anthracite coal, increasing, in a great degree, the intensity of the heat, and giving it the necessary direction through the communicating flues of the furnace, upon the bodies to be heated.

The drawings exhibit a front elevation, a ground plan, and a section; all upon a scale of six feet to an inch.

The exterior shape and proportions may be varied at pleasure, provided the principle of generating and applying the heat be retained.

With a furnace of this construction, and a moderate blast, the flame and the heat may be carried to almost any required extent under the boiler of a steam engine or other body, using anthracite coal as fuel. The blast may be obtained by attaching a small pair of tub, or other bellows, to the engine, and the machinery may be put in motion by using, in the first place, a small quantity of wood. Power enough being thus obtained to start the bellows,

no more wood will be required until after the fire has been suffered to go down, and is to be again renewed.

The coal should always be kept, while in full operation, at about the line E, or, at least, so much above the flue B, that it may become perfectly ignited before it sinks to that level. Attention to this is important in preserving a uniform temperature.

The additional power required to propel the bellows, beyond that necessary for the ordinary work to be performed by the engine, will be very small, it is believed not more than a single horse to an engine of what is called forty-horse power, or about two and a half per cent.; but should it exceed that estimate in a triple proportion, and experience justifies the conclusion that it will not, the economy of room on board of steam boats, where room is so valuable, with other advantages hereafter mentioned, and the saving, in all places, of expense in fuel, will much more than compensate this disadvantage.

But in addition to the economy effected by the introduction into general use for this object, of a fuel existing in inexhaustible quantities in our country,* to the exclusion, in many situations at least, of one daily becoming more scarce and costly, a further and important saving will result in the construction of boilers adapted to this furnace; nearly all the space now occupied by the wood, that is, the furnace part of the boiler, may be dispensed with, and in its place be substituted a narrow flue for the passage of the heat under that part of the boiler containing the water. The part that may be dispensed with, forms an expensive part of the whole, while the furnace in which the heat is to be generated, being of a less expensive material, will be much less costly. The great objection to the use of anthracite coal, in generating steam, arising from the necessity heretofore supposed to exist, of bringing the fuel in actual contact with, or near approach to, the boiler along its entire surface, is, by this plan, entirely obviated, as the coal here is never in contact with the iron, which, of course, will be much more

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* United States of America.

(FIG. 1.)

(FIC

2.)

durable than if constantly acted upon by the direct heat of the fuel.

The principle in the construction of furnaces, and the generation and application of heat by means of anthracite coal and an artificial blast, may be applied with equal advantage to the manufacture of glass, earthenware, pottery, the burning of brick, and all manufactures admitting a like application of heat.

The drawings, figs. 1, 2, and 3, represent an elevation, a vertical section, and a ground-plan, all upon a scale of six feet to an inch; and the same letters refer to the corresponding parts of each.

A A, tuyeres for introducing the blast; B B, line of flue for the passage of flame and heat under the boiler, or other

vessel, or body, to be heated; C C, charging-doors for coal; D D, cleaning-out doors, occasionally used as draught doors; E, line of upper surface of coal; F F, grate-bars. Where it is inconvenient to use these, the bottom of the furnace may be closed, as the blast will sufficiently ignite the coal; and the wood first used may be ignited by throwing open the cleaning-out doors at D D. G G, openings to promote draught, before applying blast. These may be omitted, in like manner with the bars.

The furnace should be lined with fire-brick, and cased with cast-iron plates, secured by strong bolts, screws, and keys; and between these, common brick may be used. If a thin packing, or lining of sand, be also interposed, it will be found useful in preventing injury from expansion.

SECTION VIII.

THE WEIGHT AND STRENGTH OF MATERIALS, &c.

The inaccurate experiments and discordant results which have been published at various times on these subjects, by early writers, induced Mr. John Rennie, jun. to undertake a series of exact experiments to determine, or approximate as near as possible to the truth; which he communicated in a paper to the Royal Society, in whose Transactions it is inserted at length; and believing, with the ingenious author, that they "will tend to elucidate a subject which is likely to form one of the principal branches of an engineer's education, as he must either proceed on the principle of science, or be directed by a feeling of fitness, which is to be acquired only by devoting a life-time to the practice of his art," we hesitate not to avail ourselves largely in this section of the important information it affords.

The knowledge of the properties of bodies which come

more immediately under our observation, is so instrumental to the progress of science, that any approximation to it deserves our serious attention. The Royal Society appears to have instituted, at an early period, some experiments on this subject, but they have recorded little to aid us. Emerson, in his Mechanics, has laid down a number of rules and approximations. Professor Robinson in his excellent treatise in the *Encyclopedia Britannica*, Banks on the Power of Machines, Dr. Anderson of Glasgow, Colonel Beaufoy, &c. are those, amongst our countrymen, who have given the result of their experiments on wood and iron. The subject, however, appears to have excited considerable attention on the Continent. A theory was published in the year 1638, by Galileo, on the resistance of solids, and subsequently by many other philosophers. But, however plausible these investigations appeared, they were more theoretical than practical, as will be seen in the sequel. It is only by deriving a theory from careful and well-directed experiments, that practical results can be obtained. It would be useless to enumerate the labours of those philosophers, who, in following, or varying from, the steps of Galileo, have merely tended to obscure a subject respecting which they had no data to proceed upon. It is sufficient to enumerate the names of those who, in conjunction with our own countrymen, have added their labours to the little knowledge we possess. The experiments of Buffon, recorded in the *Annals of the Academy of Sciences, at Paris*, in the years 1740 and 1741, were on a scale sufficiently large to justify every conclusion, had he not omitted to ascertain the direct and absolute strength of the timber employed. It however appears from his experiments, that the strength of the ligneous fibre is nearly in proportion to the specific gravity. Muschenbroech, whose accuracy (it is said) entitles him to confidence, made a number of experiments on wood and iron, which, by being tried on various specimens of the same materials, afforded a mean result considerably higher than other previous authorities. Experiments have also been made by Mariotte, Varignon, Perrouet,

Ramus, Roudelet, Gauthey, Navier, Aubry, and Texier de Norbeck, as also at the *Ecole Polytechnique*, under the direction of M. Prony. With such authorities before us, it might be deemed presumption in me, to offer a communication on a subject which has been previously treated by so many able men. But whoever has occasion to investigate the principles upon which any edifice is constructed, where the combination of its parts are more the result of uncertain rules than sound principle, will soon find how scanty is our knowledge on a subject so highly important. The desire of obtaining some approximation, which could only be accomplished by repeated trials on the substances themselves, induced Mr. Rennie to undertake the following experiments.

The apparatus used for this purpose was a powerful lever of the second class; it consisted of a flat bar of the best English iron, about ten feet long, one of the extremities being formed into a rule-joint, by which it was attached to a stout and short standard of wrought-iron, that was bolted to a massive bed-plate of cast-iron; the hole in the centre of the joint, and the pin which formed the fulcrum, were accurately turned, so as to move smoothly and freely. The lever was accurately divided on its lower edge, which was made straight in a line with the fulcrum. A point or division was selected, at five inches from the fulcrum, at which place was let in a piece of hardened steel. The lever was balanced by a weight, and in this state it was ready for operation. But, in order to keep it as level as possible, a hole was drilled through a projection on the bed-plate, large enough to admit a stout bolt easily through it, which again was prevented from turning in the hole by means of a tongue fitting into a corresponding groove in the hole. So that, in order to preserve the level, it was only necessary to move the nut, to elevate or depress the bolt, according to the size of the specimen. But as an inequality of pressure would still arise, from the nature of the apparatus, the body to be examined was placed between two pieces of steel, the pressure being communicated through the medium of two

pieces of thick leather above and below the steel pieces, by which means a more equal contact of surfaces was attained. The scale was hung on a loop of iron, touching the lever in an edge only. At first, a rope was used for the balance weight, which indicated a friction of four pounds, but a chain diminished the friction one half. Every moveable centre was well oiled. Of the resistances opposed to the simple strains which may disturb the quiescent state of a body, the principal are the repulsive force, whereby it resists compression, and the force of cohesion, whereby it resists extension. On the former, with the exception of the experiments of Gauthey and Rondelet on stones, and a few others on soft substances, there is scarcely any thing on record. In the memoir of M. Lagrange, on the force of springs, published in the year 1760, the moment of elasticity is represented by a constant quantity, without indicating the relation of this value to the size of the spring: but in the memoir of the year 1776, on the forms of columns, where he considers a body whose dimensions and thickness are variable, he makes the moment of elasticity proportional to the fourth power of the radius, in observing the relations of theory and practice to accord with each other. This was admitted by Euler, in his memoir of 1780, in his elaborate investigation of the forms of columns. Mr. Coulomb had however shown, before that time, how inapplicable all these calculations were to columns under common circumstances. The results of experiments have also been equally discordant; since it is deduced from those of Reynolds, that the power required to crush a cubic quarter of an inch of cast-iron is 448,000 pounds avoirdupois, or 200 tons; whereas, by the average of thirteen experiments made by Mr. Rennie, on cubes of the same size, the amount never exceeded 10392·53 lbs. not quite five tons. This may be seen by referring to the tables. There were four kinds of iron used, *viz.* 1. Iron taken from the centre of a large block, whose crystals were similar in appearance and magnitude to those evinced in the fracture of what is usually termed gun-metal. 2. Iron taken from a

small casting, close grained, and of a dull grey colour. 3. Iron cast horizontally, in bars of $\frac{3}{8}$ths of an inch square, eight inches long. 4. Iron cast vertically, same size as last. These castings were reduced equally on every side to one quarter of an inch square; thus removing the hard external coat usually surrounding metal castings. They were all subjected to a guage; the bars were then presumed to be tolerably uniform. The weights used were of the best kind that could be procured, and, as the experiment advanced, smaller weights were used.

As we have not space for detailing the particulars of each experiment, we here add only the *average* results of them.

The experiments on cast-iron in cubes of $\frac{1}{8}$th of an inch, —specific gravity 7.033, gave 1439 lbs. avoirdupois, as the average.

On specimens of the same iron, $\frac{1}{8}$ inch square, and $\frac{1}{4}$ inch long, the average force required was 2116 lbs.

On specimens of the same thickness, but varying in length from $\frac{1}{2}$ inch to 1 inch, the average result was 1758 lbs.

On cubes of a quarter of an inch of the same metal, gave 9773 lbs. as the average result.

On $\frac{1}{4}$ inch cubes, made from horizontal castings of specific gravity 7.113, gave 10,114 lbs. as the average.

On $\frac{1}{4}$ inch cubes, vertical castings, specific gravity 7.074, the average was 11,136 lbs.

A prism, having a logarithmic curve for its limits, resembling a column, it was $\frac{1}{4}$ of an inch diameter by 1 inch long, broke with 6954 lbs.

The trials on prisms of prisms of different lengths $\frac{1}{4} \times \frac{1}{2}$ horizontal, gave 9414 lbs.

The same, vertical, gave 9982 lbs.

Horizontal castings, varying from $\frac{3}{8}$ to $\frac{5}{8}$ inch $\times$ $\frac{1}{4}$, gave an average of 8738 lbs.

Vertical ditto, gave 8536 lbs.

Experiments on different Metals.

$\frac{1}{4}\times\frac{1}{4}$ cast copper, crumbled with	....	7318 lbs.
$\frac{1}{4}\times\frac{1}{4}$ fine yellow brass reduced $\frac{1}{10}$ with $3213\frac{1}{2}$ lbs. with	....	10304
$\frac{1}{4}\times\frac{1}{4}$ wrought copper .... $\frac{1}{16}$ .... $3427\frac{1}{8}$	....	6440
$\frac{1}{4}\times\frac{1}{4}$ cast tin .... $\frac{1}{17}$ .... $552\frac{1}{4}$	....	966
$\frac{1}{4}\times\frac{1}{4}$ cast lead .... $\frac{1}{2}$	....	463

The experiments on the different metals gave no satisfactory results. The difficulty consists in assigning a value to the different degrees of diminution. When compressed beyond a certain thickness, the resistance becomes enormous.

Experiments on the Suspension of Bars.

The lever was used as in the former case, but the metals were held by nippers. They were made of wrought-iron, and their ends adapted to receive the bars, which, by being tapered at both extremities, and increasing in diameter from the actual section, and the jaws of the nippers being confined by a hoop, confined both. The bars, which were six inches long and $\frac{1}{4}$ square, were thus fairly and firmly grasped.

$\frac{1}{4}$ inch cast-iron, horizontal	1166 lbs.
$\frac{1}{4}$ ditto ditto, vertical	1218
$\frac{1}{4}$ ditto cast-steel, previously tilted	8391
$\frac{1}{4}$ ditto blister steel, reduced per hammer	8322
$\frac{1}{4}$ ditto shear steel, ...ditto................	7977
$\frac{1}{4}$ ditto Swedish iron ......ditto................	4504
$\frac{1}{4}$ ditto English iron ......ditto................	3492
$\frac{1}{4}$ ditto hard gun metal, mean of two trials	2273
$\frac{1}{4}$ ditto wrought copper, reduced per hammer	2112
$\frac{1}{4}$ ditto cast copper	1192
$\frac{1}{4}$ ditto fine yellow brass........................	1123
$\frac{1}{4}$ ditto cast tin................................	296
$\frac{1}{4}$ ditto cast lead	114

Remarks on the last Experiments.

The ratio of the repulsion of the horizontal cast cubes to the cohesion of horizontal cast bars, is 8.65 : 1.

The ratio of the vertical cast cubes to the cohesion of the vertical cast bars, is as 9.14 : 1.

The average of the bars, compared with the cubes, is as 10.611 : 1.

The other metals decrease in strength, from cast steel to cast lead.

The stretching of all the wrought bars indicated heat.

The fracture of the cast bars was attended with very little diminution of section, scarcely sensible.

The experiment made by M. Prony (who asserts, that by making a slight incision with the file, the resistance is diminished one half,) was tried on a ¼ inch bar of English iron; the result was 2920 lbs. not a sixth-part less.

This single experiment, however, does not sufficiently disprove the authority of that able philosopher, for an incision is but a vague term. The incision I made might be about the fortieth part of an inch.

Experiments on the Twist of ¼ inch Bars.

To effect the operation of twisting off a bar, another apparatus was prepared. It consisted of a wrought-iron lever, two feet long, having an arched head about one-sixth of a circle, of four feet diameter, of which the lever represented the radius; the centre, round which it moved, had a square hole made to receive the end of the bar to be twisted. The lever was balanced as before, and a scale hung on the arched head; the other end of the bar being fixed in a square hole in a piece of iron, and that again in a vice. By this apparatus, ¼ inch bars from horizontal castings were twisted with weights in the scale averaging 9 lbs. 15 oz. The vertical castings took 10 lbs. 10 oz. as an average.

On different Metals.

Cast steel	17 lbs.	9 oz. in the scale
Shear steel	17	1
Blister steel	16	11
English iron, wrought............	10	8

Swedish iron, wrought..........	9lbs.	8oz.	in the scale
Hard gun metal................	5	0	
Fine yellow brass	4	11	
Copper, cast	4	5	
Tin	1	7	
Lead..........................	1	0	

On Twists of different lengths.

HORIZONTAL.

	lbs.	oz.	
¼ by ½ long	7	3	weight in scale.
¼ by ¾ ditto	8	1	
¼ by 1 inch ditto	8	8	

VERTICAL.

¼ by ½ ditto..................	10	1	
¼ by ¾ ditto	8	9	
¼ by 1 inch ditto	8	5	

Horizontal twists of ¼ inch bars, at six inches from the bearing, took an average of 9 lb. 12 oz. in the scale.

Twist of ½ inch square Bars, cast horizontally.

	qrs.	lbs.	oz.	
½ close to the bearing	3	9	12	end of the bar hard
½ ditto	2	18	0	middle of the bar.
½ at 10 inches from bearing, lever in the middle	1	24	0	

On Twists of different Materials.

These experiments were made close to the bearing, and the weights were accumulated in the scale until the substances were wrenched asunder.

	lbs.	oz.	
Cast steel	19	9	weight in scale.
Shear steel	17	1	
Blister steel	16	11	
English iron, No. 1	10	2	
Swedish iron	9	8	
Hard gun metal................	5	0	
Fine yellow brass	4	11	
Copper	4	5	
Tin	1	7	
Lead	1	0	

Remarks.

Here the strength of the vertical bars still predominates.

The average of the two taken conjointly, and compared with a similar case of ½ inch bars, gives the ratio as the cubes, as was anticipated.

In the horizontal castings of different lengths, the balance is in favour of the increased lengths; but in the vertical castings, it is the reverse. In neither is there any apparent ratio. In the horizontal castings, at six inches from the bearing, there is a visible increase, but not so great as when close to the bearing.

Miscellaneous Experiments on the Crush of one cubic inch.

Elm	1284 *lbs. avoir.*
American Pine	1606
White deal	1928
English oak, mean of two trials	3860
Ditto, of five inches long, slipped with	2572
English oak, of four inches long, slipped with	5147*
A prism of Portland stone, two inches long	805
Ditto, statuary marble	3216
Craig Leith	8688

In the following experiments on stones, the pressure was communicated through a kind of pyramid, the base of which rested on the hide leather, and that on the stone.† The lever pressed upon the apex of the pyramid. The cubes were of one and a half inch.

* The experiments on woods are considerably below those of other writers, and it appears singular that the four-inch specimen should be stronger than the shorter length. According to Rondelet's experiments, to crush a cubic inch of oak it required from 5000 to 6000 pounds avoirdupois; of fir, from 6000 to 7000 pounds. In the former, the pieces were compressed one-third of their length; in the latter, one-half of their length, (Rondelet's l'Art de Bâtir, tom. iv. p. 67.) Mr. Rennie has not stated the diminution of length.

† It certainly would have been preferable to have placed a hard and rigid substance next the stone, in order to secure equality of pressure.

	Spec. grav.	lbs. av
Chalk		1127
Brick, of a pale red colour	2.085	1265
Roe-stone, Gloucestershire		1449
Red brick, mean of two trials	2.168	1817
Yellow-faced baked Hammersmith paviours, three times		2254
Burnt ditto, mean of two trials		3243
Stourbridge, or fire-brick		3864
Derby grit, a red friable sand-stone	2.316	7076
Ditto, from another quarry	2.428	9776
Killaly white freestone, not stratified	2,423	10264
Portland	2.428	10284
Craig Leith, white freestone	2.452	12346
Yorkshire paving, with the strata	2.085	12856
Ditto, against the strata	2.507	12856
White statuary marble, not veined	2.760	13632
Bramley Fall sandstone, near Leeds, with the strata	2.506	13632
Ditto, against the strata	2.506	13632
Cornish granite	2.662	14302
Dundee sandstone or brescia, two kinds	2.530	14918
A two-inch cube of Portland	2.423	14918
Craig Leith, with the strata	2.452	15560
Devonshire red marble, variegated		16712
Compact limestone	2.584	17354
Peterhead granite, hard close-grained		18636
Black compact limestone, Limerick	2.598	19924
Purbeck	2.599	20610
Black Brabant marble	2.697	20742
Very hard freestone	2.528	21254
White Italian veined marble	2.726	21783
Aberdeen granite, blue kind	2.625	24556

N.B. The specific gravities were taken with a delicate balance, made by Creighton of Glasgow, all with the exception of two specimens, which were by accident omitted.

Remarks.

In observing the results presented by the preceding table, it will be seen that little dependence can be placed on the specific gravities of stones, so far as regards their repulsive powers, although the increase is certainly in favour of their specific gravities. But there would appear to be some undefined law in the connexion of bodies, with

which the specific gravity has little to do. Thus, statuary marble has a specific gravity above Aberdeen granite, yet a repulsive power not much above half the latter. Again, hardness is not altogether a characteristic of strength, inasmuch as the limestones, which yield readily to the scratch, have nevertheless a repulsive power approaching to granite itself.

Experiments made on the transverse Strain of cast Bars, the Ends loose.

	Weight of the bars.		Distance of bearings.		
	lbs.	*oz.*	*ft.*	*in.*	*lbs. av.*
Bar of 1 inch square	12	6	3	0	897
Ditto of 1 inch ditto	9	8	2	8	1086
Half the above bar			1	4	2320
Bar of 1 inch square through the diagonal	2	8	2	8	851
Half the above bar			1	4	1587
Bar of 2 inches deep, by ½ inch thick	9	5	2	8	2185
Half the above bar			1	4	4508
Bars 3 inches deep, by ⅓ inch thick	9	15	2	8	3588
Half the bar			1	4	6854
Bar 4 inches, by ¼ inch thick	9	7	2	8	3979
Equilateral triangles, with the angles up and down, *viz.* with the edge or angle up	9	11	2	8	1437
With the angle down	9	7	2	8	840
Half the first bar			1	4	3059
Half the second bar			1	4	1656
A feather-edged bar was cast, whose dimensions were 2 inches deep by 2 wide, edge up	10	0	2	8	3105

N.B. All these bars contained the same area, though differently distributed as to their forms.

Experiments made on the Bar of 4 inches deep by ¼ inch thick, by giving it different forms, the bearings at 2 feet 8 inches, as before.

	lbs.
Bar formed into a semi-ellipse, weighed 7 lbs	4000
Ditto, parabolic on its lower edge	3860
Ditto of 4 inches deep by ¼ inch thick	3979

Experiments on the transverse strain of Bars, one end made fast, the weight being suspended at the other, at 2 feet 8 inches from the bearing.

An inch-square bar bore	280 lbs.
A bar 2 inches deep by ½ an inch thick....................	539
An inch bar, the ends made fast	1173

The paradoxical experiment of Emerson was tried, which states, that by cutting off a portion of an equilateral triangle (see page 114, of Emerson's Mechanics,) the bar is stronger than before; that is, a part stronger than the whole. The ends were loose, at two feet eight inches apart, as before. The edge from which the part was intercepted was lowermost, the weight was applied on the base above; it broke with 1129 pounds, whereas, in the other case, it bore only 840 pounds.

Remarks on the transverse Strain.

Mr. Banks makes his bar from the cupola, when placed on bearings three feet asunder, and the ends loose, to bear 864 pounds.

All Mr. Rennie's bars were cast from the cupola, the difference was therefore 33 pounds. He adopted a space of two feet eight inches asunder, as being more convenient for his apparatus. The strength of the different bars, all cases being the same, approaches nearly to the theory which makes the comparative values *as the breadths multiplied into the squares of the depths*. The halves of the bars were tried, merely to keep up the analogy; the bar of four inches deep, however, falls short of theory by 365 pounds. It is evident we cannot extend the system of deepening the bar much further, nor does the theory exactly maintain in the case of the equilateral triangle, by 243 pounds.

The diagonal position of the square bar, is actually worse than when laid on its side, contrary to many assertions.

The same quantity of metal in the feather-edged bar, was not so strong as in the four-inch bar.

The semi-elliptical bar exceeded the four-inch bar, although taken out of it. The parabolic bar came near it.

Observations by various Authors on the Strength of Materials.

A wire of $\frac{1}{10}$th of an inch of lead, breaks with $29\frac{1}{4}$ lbs., of tin, with $49\frac{1}{4}$ lbs.; of copper, with $299\frac{1}{4}$; of brass, with 360; of silver, with 370; of iron, with 450.—*Emerson.*

A cylinder, an inch in diameter, will bear, when loaded to $\frac{1}{4}$ of its whole strength, if of fir, 8.8 cwt.; if of rope, 22 cwt.; if of iron, 135 cwt.—*Emerson.*

The cohesive strength of a cylinder of iron, an inch in diameter, is 63,466 or 63,173 pounds, the mean 63,320 pounds, which is 28 tons, 5 cwt. 1 qr. 12 lbs.—*Rumford.*

The comparative cohesive strength of gold, is as 150,955; of silver, 190,771; of platina, 262,361; of copper, 304,696; of soft iron, 362,927; of hard iron, 559,880.—*Sickengen.*

The hardness of metals follows this order,—iron, platina, copper, silver, gold, tin, lead.—*Cavallo.*

In general, iron is about four times as strong as oak, and six times as strong as deal.—*Banks.*

Wood is from 7 to 20 times weaker transversely than longitudinally. It becomes stronger both ways when dry.

A piece of sound oak, an inch square, bears 8000 pounds directly, and is broken transversely by 200, at the distance of 12 inches from the fulcrum.—*Robison.*

The immediate transverse strength of lateral adhesion of most substances exceeds their direct cohesive strength, but the difference is less in fibrous substances than in others.—*Robison.*

The strongest form of a substance included by horizontal surfaces, for supporting a weight at its extremity, is that of a triangle. The same form is also the stiffest.—*Emerson.*

For supporting a weight distributed uniformly throughout its length, the form must be that of a parabola.—*Emerson.*

A triangular prism fixed at one end, with its edge uppermost, is weaker than if its depth were reduced to eight-ninths, by cutting away the edge.—*Emerson.*

If a piece be sliced in a divided beam, equal in depth to half the depth of the beam, the strength is greater than that of the entire beam, in the ratio of 1 to 1.054, very nearly.—*Robison.*

A mortise-hole should be taken out of the middle of a beam, not from one side; but if it be on the concave side, and fitted up with hard wood, it does not diminish the strength.—*Emerson.*

If a cylinder is to be supported at two points with the least strain, the distance between the points should be .5858 of the length.—*Emerson.*

A soft iron bar, a spring tempered, and a hard one, were bent to equal angles by five pounds; with six, the hard bar broke; with seven, the soft one bent, but returned as far from its new position, upon the removal of the weight, as if it had not been bent. The elastic bar was broken by 18 pounds.—*Coulumb.*

Weight of one Foot in length of flat Bar-iron.

Broad	Thick	Weight in pounds.
½ inch	⅛ inch	0.21
	3/16	0.31
	¼	0.42
	⅜	0.63
¾ inch	⅛ inch	0.31
	3/16	0.47
	¼	0.63
	⅜	0.94
	½	1.26
	⅝	1.57
1 inch	⅛ inch	0.42
	3/16	0.63
	¼	0.84
	⅜	1.26
	½	1.68

Broad	Thick	Weight in pounds.
1 inch	⅝ inch	2.10
	¾	2.52
	⅞	2.94
1¼ inch	⅛ inch	0.52
	3/16	0.78
	¼	1.05
	⅜	1.57
	½	2.10
	⅝	2.62
	¾	3.15
	⅞	3.67
	1	4.20
	1⅛	4.72
1⅜ inch	⅛ inch	0.57
	3/16	0.86

Broad	Thick	Weight in pounds.
1⅜ inch	¼ inch	1.18
	⅜	1.73
	½	2.31
	⅝	2.88
	¾	3.46
	⅞	4.04
	1	4.62
	1⅛	5.19
	1¼	5.77
1½ inch	⅛ inch	0.63
	3/16	0.94
	¼	1.26
	⅜	1.89
	½	2.52
	⅝	3.15
	¾	3.75

Broad	Thick	Weight in pounds.
1½ inch	⅞ inch	4.41
	1	5.04
	1⅛	5.67
	1¼	6.30
1¾ inch	⅛ inch	0.73
	3/16	1.10
	¼	1.47
	⅜	2.20
	½	2.94
	⅝	3.67
	¾	4.41
	⅞	5.14
	1	5.87
	1⅛	6.60
	1¼	7.35
	1⅜	8.07
	1½	8.80
2 inch	⅛ inch	0.84
	3/16	1.26
	¼	1.68
	⅜	2.52
	½	3.36
	⅝	4.20
	¾	5.04
	⅞	5.88
	1	6.72
	1⅛	7.56
	1¼	8.40
	1⅜	9.24
	1½	10.08
2¼ inch	⅛ inch	0.94
	3/16	1.41
	¼	1.89
	⅜	2.83
	½	3.78
	⅝	4.72
	¾	5.66
	⅞	6.61
	1	7.56
	1⅛	8.50
	1¼	9.45
	1⅜	10.39
	1½	11.34
2¼ inch	1¾ inch	13.22
	2	15.12
2½ inch	⅛ inch	1.05
	3/16	1.57
	¼	2.10
	⅜	3.15
	½	4.20
	⅝	5.25
	¾	6.30
	⅞	7.35
	1	8.40
	1⅛	9.55
	1¼	10.50
	1½	12.60
	2	16.80
2¾ inch	⅛ inch	1.15
	3/16	1.73
	¼	2.31
	⅜	3.46
	½	4.62
	⅝	5.77
	¾	6 93
	⅞	8.08
	1	9.24
	1⅛	10.39
	1¼	11.55
	1½	13.86
	2	18.48
	2½	23.10
3 inch	⅛ inch	1.26
	3/16	1.89
	¼	2.52
	⅜	3.78
	½	5.04
	⅝	6.30
	¾	7.56
	⅞	8.82
	1	10.08
	1⅛	11.34
	1¼	12.60
	1½	15.12
	2	20.16
	2½	25.20
3¼ inch	⅛ inch	1.36
	3/16	2.04
	¼	2.73
	⅜	4.09
	½	5.46
	⅝	6.82
	¾	8.19
	⅞	9.55
	1	10.92
	1⅛	12.28
	1¼	13.65
	1½	16.38
	2	21.84
	2½	27.39
	3	32.76
3½ inch	⅛ inch	1.47
	3/16	2.20
	¼	2.94
	⅜	4.41
	½	5.88
	⅝	7.35
	¾	8.82
	⅞	10.29
	1	11.76
	1¼	14.70
	1½	17.64
	2	23.52
	2½	29.40
	3	35.28
3¾ inch	⅛ inch	1.57
	3/16	2.36
	¼	3.15
	⅜	4.72
	½	6.30
	⅝	7.87
	¾	9.45
	⅞	11.02
	1	12.60
	1¼	15.75
	1½	18.90
	2	25.20
	2½	31.50
	3	37.80